



RIACS FY2001 Annual Report

Barry M. Leiner

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Any opinions, findings, and conclusions or recommendations expressed in this material are those of the author(s) and do not necessarily reflect the views of the National Aeronautics and Space Administration.

This report is available online at <http://www.riacs.edu/trs/>

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I Introduction and Overview

The Research Institute for Advanced Computer Science (RIACS) carries out basic research and technology development in computer science, in support of the National Aeronautics and Space Administration's missions. RIACS is located at the NASA Ames Research Center, Moffett Field, California. It currently operates under a multiple year grant/cooperative agreement that began on October 1, 1997 and is up for renewal in September 2002.

Ames has been designated NASA's Center of Excellence in Information Technology. In this capacity, Ames is charged with the responsibility to build an Information Technology (IT) Research Program that is preeminent within NASA. RIACS serves as a bridge between NASA Ames and the academic community, and RIACS scientists and visitors work in close collaboration with NASA scientists. RIACS has the additional goal of broadening the base of researchers in these areas of importance to the nation's space and aeronautics enterprises.

RIACS research focuses on the three cornerstones of IT research necessary to meet the future challenges of NASA missions:

- **Automated Reasoning for Autonomous Systems**
Techniques are being developed enabling spacecraft that will be self-guiding and self-correcting to the extent that they will require little or no human intervention. Such craft will be equipped to independently solve problems as they arise, and fulfill their missions with minimum direction from Earth.
- **Human-Centered Computing**
Many NASA missions require synergy between humans and computers, with sophisticated computational aids amplifying human cognitive and perceptual abilities.
- **High Performance Computing and Networking**
Advances in the performance of computing and networking continue to have major impact on a variety of NASA endeavors, ranging from modeling and simulation to analysis of large scientific datasets to collaborative engineering, planning and execution.

In addition, RIACS collaborates with NASA scientists to apply IT research to a variety of NASA application domains. RIACS also engages in other activities, such as workshops, seminars, visiting scientist programs and student summer programs, designed to encourage and facilitate collaboration between the university and NASA IT research communities.

I.A Summary of FY2001 Activity

During the year October 1, 2000 through September 30, 2001, RIACS engaged in a number of research projects collaboratively with NASA scientists. Over 180 publications and presentations resulted from this work. Section II describes each of those projects along with a list of publications. In addition, RIACS continued to run a successful bi-weekly seminar series, augmented with special seminars, as well as support and participate in a number of workshops. During FY2001, we hosted 49 seminars and supported three workshops. RIACS also maintains an

online library of the technical reports generated by staff scientists, and provides hard copies to interested parties upon request. 23 technical reports were produced this year. The seminars, workshops and technical reports are shown in Section III. Finally, RIACS continued the Ames/RIACS Summer Student Research Program (SSRP), a competitive program in which selected students spend the summer at Ames working with Ames researchers. A description of the students' specific efforts may be found in Section II.E.1.

In addition to participating in initiatives by others at Ames (described in the various projects below), we have initiated several activities. We have continued to work with Ames personnel in establishing an Ames thrust in spoken dialogue natural language interfaces. We anticipate an organizational transition (from a RIACS activity to an integrated Ames activity) to complete during this coming year. See Section II.B.2 for more detail.

Complementary to the thrust in High Dependability Computing (initiated by Ames), RIACS sponsored a workshop on "Verification and Validation of Autonomous and Adaptive Systems". We anticipate the results of this workshop will influence future work in the area. See Section II.A.1.e for more detail.

In support of Ames interest in leveraging its strengths in biology, astrobiology, nanotechnology, and IT, RIACS is working with USRA to organize a community forum/workshop to discuss such leverage against the needs of space-based research. We anticipate this symposium to be held in the spring. See Section I.B for more detail.

Information management technologies are important to NASA and more generally, the public sector. We recently initiated a panel study into the information management technology requirements for applications of particular government interest, such as digital libraries, mission operations, and science data management. Supported by NASA, NSF, and DARPA, we anticipate the results of the study to be available by the end of the coming fiscal year. See II.B.5 for more detail.

NASA Ames has several activities ongoing in the area of collaboration technologies and their application to NASA missions and programs. Recognizing the value of sharing information across these various activities, we have collaborated with Val Watson (Code IN) in initiating a discussion group called "Collaboration on Collaboration". The group meets regularly and the intent is for it to spawn collaborative projects.

After substantial growth in prior years (from 4 scientists in October 1997 to 40 in October 2000), the number of staff scientists dropped some over this year, to 35. This was primarily due to six scientists (including the former RIACS Deputy Director, Robert Morris) electing to join the civil service. (We should note that this is a positive, as it underscores the role that RIACS can play in engaging high quality scientists from the university community to work as part of the Ames projects.) In addition, three scientists, Daniel Clancy, Butler Hine, and David Maluf, are now on loan to NASA under the IPA program. 39 visiting scientists and 21 visiting students spent time at RIACS during the year. Section IV provides more detail on staffing.

Several areas of activity at RIACS have multiple projects that are related. Recognizing the benefits of coordinating across such projects, three Associate Directors were named. Kathleen Connell is responsible for projects investigating the synergies of biology and astrobiology activities with IT. Kanna Rajan is responsible for projects in autonomous systems, including topics such as automated reasoning, planning and scheduling. Johann Schumann is responsible for projects in software engineering, including the areas of software synthesis, verification and validation, and distributed frameworks. Their overviews of these areas follow.

1.B Bio/IT Fusion Area Overview

Kathleen Connell (Associate Director)

The Bio/IT group within RIACS is composed of staff who work at the intersection of biology and information technologies.

For over 15 years, NASA/Ames has explored the potential of “innovation at the intersection of disciplines” as a possible strategic thrust. In 1995 Kathleen Connell, in conjunction with NASA collaborators, co-created a team at Ames which gave scientific structure to this organizing principle, in the creation of the discipline now known as astrobiology. This multidisciplinary program seeks to answer fundamental questions about the origin, evolution and distribution of life in the universe, and has become a major scientific thrust for the Agency.

Other compelling opportunities have presented themselves to NASA and the university space community, as the “biology century” is fully underway in 2001. The accomplishments of the Human Genome project, and related bio-technical private sector initiatives, are increasingly inseparable from a “fusion” of basic biologic inquiry with the tools that information technologies provide. NASA Headquarters acknowledged the importance of integrative work with a recent call to universities for proposals that explore the research/technology triangle of biology, information systems, and nanotechnologies (BIN) and their applications, to all aspects of the space program. The Bio/IT Associate Director has arranged a USRA/RIACS/NASA effort in BIN science and technology, and integration of these into NASA missions. The kick off event of this collaboration is a conference and workshop to be held in June, 2002.

RIACS Bio/IT team members are found in lead positions in fields such as: bio-informatics, knowledge management in astrobiology, concept visualization and integrative knowledge creation (think- and web-tanking), 3D reconstruction and visualization of biological systems, and bio/it/nano/society program planning, - to name but a few areas of cutting edge RIACS expertise.

Current Projects: Highlights

Bio-Evolutionary Advanced Concepts for NASA (BEACON) (RIACS Lead: Zann Gill)

BEACON will provide a context and method to generate and incubate innovative concepts involving NASA researchers and university collaborators in cross-disciplinary project and program development and engage a broad visionary community in the design of NASA missions. To accomplish this end it will be:

- a vehicle through which NASA can achieve breakthroughs at the disciplinary interface of information science and technology, biology, and astrobiology;
- a neutral ground for universities and industry to collaborate with NASA on advanced concepts and collaborative R&D that can spawn new NASA Institutes;
- a way to accelerate “the four I’s of BEACON”:
 - basic inquiry,
 - process and technology innovation,
 - insertion of new processes and technologies into NASA missions, and
 - project integration.

Virtual Glovebox (RIACS Lead: Xander Twombly)

Computer science research at the Ames Center for Bioinformatics is focused primarily on the development of advanced 3D reconstruction and visualization techniques for cell biology and medical research. RIACS staff provides technical leadership for CS projects in the center. The primary project was the design and initial implementation of the NASA Virtual GloveboX (VGX), a virtual environment simulation tool for evaluating and training astronauts on biological experiment procedures. The VGX is a long-term project to develop a fully immersive environment for simulating animal surgeries and other biological experiments expected to be performed on the International Space Station. The VGX will be comprised of a virtual display covering the same physical dimensions of the actual Life Sciences Glovebox (LSG), and a set of haptic feedback devices for allowing interaction with the simulated biological data sets. The VGX will also be used for procedural training, and refresher training onboard the ISS prior to astronauts performing a specific surgical procedure. The VGX is an extension of the technologies developed in 1999 that comprised the Virtual Collaborative Clinic (VCC).

NASA Astrobiology Institute Collaboration Technology (RIACS Lead: Lisa Faithorn)

The NASA Astrobiology Institute (NAI) was established in 1998 to encourage and fund collaborative multidisciplinary research in astrobiology and to foster innovative contributions to the scientific research agendas of NASA space missions. NAI represents a partnership between NASA and a number of academic institutions and research organizations and is currently composed of 15 lead research teams, which together represent over 700 investigators located at over one hundred institutions across the United States. The NAI administrative group, known as NAI Central, is situated at Ames Research Center.

Since an overarching shared goal of the NAI and its members is innovative research in astrobiology with an emphasis on collaborative work, both within and among its geographically distributed teams, NAI was conceived from the beginning to operate as a “virtual institute”. To meet its virtual institute objectives NAI planned for the deployment of various communication/collaboration tools (hardware and software), the development of community building efforts including opportunities for scientific interaction potentially leading to new collaborations within and among NAI Teams, and on-going evaluation of collaboration support in order to continuously develop and improve the effectiveness of NAI.

RIACS supports the continued development of NAI by staffing the role of NAI Collaborative Research Manager. The primary responsibility of this role is to provide leadership in defining, evolving, implementing, and maintaining an integrated collaborative infrastructure, including the appropriate technology architecture that will support the goals of the NAI as a virtual institute.

Computational and Structural Genomics (RIACS Lead: Karl Schweighofer)

This task is focused on research in computational/structural genomics, and leading the effort to provide NASA Ames with a resource which will allow researchers to perform individual analyses and share data in a way that is not possible using current, publicly available databases.

The research supporting the NASA Center for Computational Astrobiology and Fundamental Biology (NCCAFB) has two main objectives. One is the development of novel algorithms and methods to analyze genomic and expression data. The other is to use these tools to a) formulate hypotheses of how essential cellular functions arose, and evolved, b) probe the molecular basis for physiological changes due to microgravity, and c) leverage sequence, expression, and structural data to create more reliable molecular models and simulations. Infrastructure work concentrates on establishing code and data repositories, including methods for quality control, building essential public genomics tools, and their deployment for use by the NASA community in an integrated fashion.

RIACS Bio/IT Staff (as of 30 Sep 01)

Kathleen Connell, Associate Director

Lisa Faithorn

Susan Gill

Karl Schweighofer

Xander Twombly

Senior Team Advisor: Lewis Peach, Chief Engineer, USRA

I.C Autonomous Systems Area Overview

Kanna Rajan (Associate Director)

Autonomous systems are increasingly not just relevant, but critical for NASA in its goal for an aggressive exploration program of deep space. Within current budgetary constraints, the agency has been asked to do more with less. In addition, the scientific community has charted out a path towards a more aggressive goal of space exploration and use of space – both near earth and deep space. As a consequence, the kinds of missions the agency is currently evaluating are markedly different from those as recent as 10 to 15 years ago. No longer are class A Cassini style missions (costing in the billions of dollars) the norm. Rather, the notion of using smaller and more agile spacecraft demonstrated in numerous recent missions such as NEAR, Mars Path Finder, Mars Global Surveyor, Deep Space One, have validated the concept of a small well designed platform being able to accomplish substantial science as well as new technology. This “faster better cheaper” approach to mission enablement has also brought out the need for substantially larger numbers of missions to be developed and deployed in shorter time periods. The result has been to reuse not just hardware platforms but also software systems controlling the vehicle and its instruments onboard. This has also resulted in increased human operations costs as the skill sets

needed to fly this larger set of spacecraft are widely in demand. To further add to the mix, the communication costs associated with maintaining the Deep Space Network and utilizing its scarce available bandwidth are rising steeply.

Within this context, the agency has made a crucial push towards automating routine operations on the ground and pushing closed loop autonomous control onboard. The agency has also been keenly aware that to explore newer worlds with large light-time distance, the most effective way for enablement is to put autonomy onboard. For example, a highly autonomous rover with smart resource management software could not only systematically explore and traverse large tracts of the Martian surface, but could also conserve power to handle serendipitous scientific activity. A potential underwater mission to the oceans of Europa will not be conceivable without substantial onboard autonomy. Autonomy is also highly desirable when menial tasks can be offloaded to a software assistant executing on a micro-robot that faithfully executes the tasks for an astronaut onboard the International Space Station, thereby saving valuable human time, energy and effort.

The core concept behind autonomy is the ability to close a control loop using a principled software architecture. This involves the need to sense, deliberate and act to the changing environmental conditions. RIACS staff at NASA Ames are central to this theme and are among the leaders in the artificial intelligence community in shaping the vision of autonomous systems for the agency. The work described in this area includes Planning, Execution and Diagnosis – the key elements of the control cycle. The foundation of the work in this group is built on the efforts of designing, writing, testing and flying the Remote Agent (RA) closed loop autonomous system that flew onboard NASA's Deep Space One spacecraft in May 1999. The lessons learned from that effort are now the main drivers of the research effort in this area. R. Dearden and A. Bajwa have been pushing the state of the art in hybrid diagnosis for situation and resource estimations in real world problems. On the RA, the state estimation and diagnostics was based on discrete monitor values from the sensors of the spacecraft. Clearly such an approach has limitations when the vehicle interacts closely with its environment such as a rover on Martian terrain. The application of such efforts is already underway with the first steps being taken to build a closed loop diagnostician on board NASA's X vehicles. R. Washington's efforts are towards using utility based approaches for robust plan execution for rovers, online resource management and flexible plan management. A. Jonsson and K. Rajan have been working on constraint-based planning approaches to solve real world planning problems such as those on the RA and scheduling for earth-observing spacecraft using time and resources within the plan representations. Concepts generated by this work are being used for situations where a human in the loop is necessary as well as when automated approaches are critical for commanding spacecraft. Finally, also in the rover domain, E. Bandari and J. Loch targeted their research efforts on robust efforts in target tracking and visual servoing and for plan selection using conditional action selection using reinforcement learning techniques.

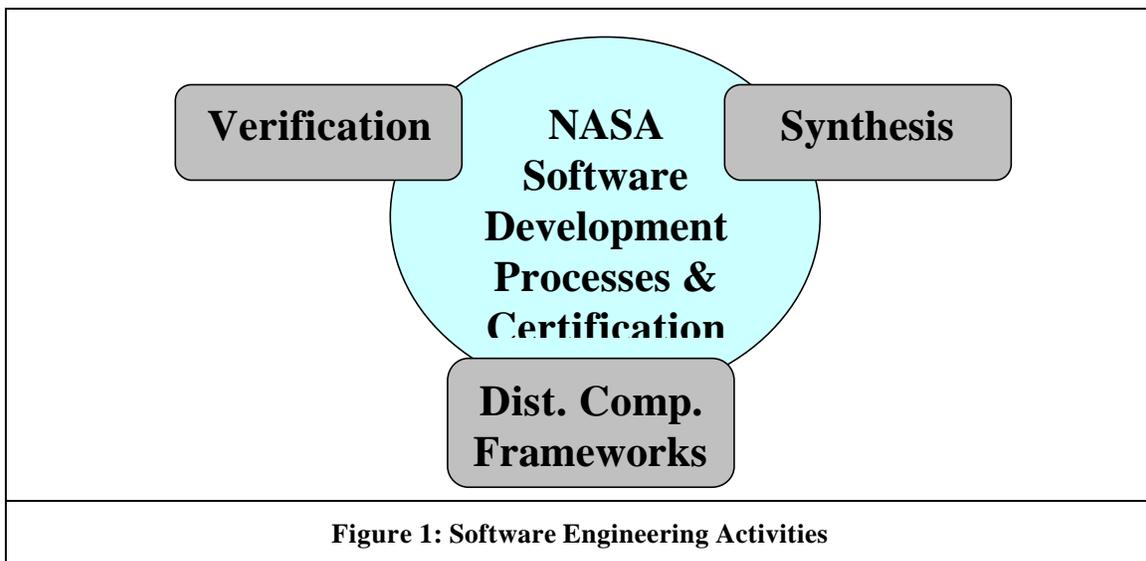
Building autonomous systems for real world applications is a fundamentally challenging task and efforts in this area are critical to pushing the state of the art for control systems for future NASA spacecraft. To fulfill the ambitious needs of the agency, the Autonomous Systems area is at the center of efforts within the agency to make it happen.

RIACS Autonomous Systems Staff (as of 30 Sep 01)

Kanna Rajan, Associate Director
 Anupa Bajwa
 Esfandiar Bandari
 Richard Dearden
 Ari Jonsson
 John Loch
 Richard Washington

I.D Software Engineering Area Overview
 Johann Schumann (Associate Director)

Several recent mission failures have been attributed to software-related glitches: Mars Climate Orbiter failed because of a mismatch of unit systems (meter and kilograms vs. feet and pound); Mars Polar Lander probably crashed because an erroneous signal from a landing sensor was not processed appropriately and therefore directly caused the rocket engine to be cut. The international space station (ISS) was uncontrollable for a period of time because, after a hardware failure (disk crash), this exception was not propagated and handled in a correct way, thus disabling the backup processing units. In general, under the paramount goal of “faster, better, cheaper”, software and its development (process) are becoming a critical issue for NASA.



The *Software Engineering* area of RIACS was created to address NASA’s needs with this regard. Its global structure is shown in Figure 1. The sub-area of NASA Software Development Processes and Certification works on important issues on *how* NASA can develop and deploy software in an orderly fashion. In particular, for safety-critical software (esp. for manned missions or aviation-related tasks), *certification* is extremely important to guarantee that things cannot go wrong. This research theme relies on and is supported by three equally important pillars which help to accomplish these goals:

Verification is a methodology to formally demonstrate that a program (or software system) fulfills certain properties (e.g., memory safety), or that certain situations can never occur (e.g., deadlock between multiple processes). More specifically, this area is comprised of the following projects:

- Java Pathfinder is a model checker which, given a Java program, can automatically check if a certain property holds or is violated in certain (often hard to find) cases. This tool now has been released and enjoys a growing number of regular users. Java Pathfinder is being extended to enhance its usability by the software engineer (e.g., by a Java Runtime Monitor, and automatic abstraction).
- With higher and more complex levels of autonomy required for all areas of modern missions, more and more autonomy software is being developed. Because such pieces of software (e.g., planning systems, failure detection, isolation and recovery) are central and important for mission success, *verification of autonomy software* is an important topic. Our sub-area addresses this topic in two projects: system-level verification (i.e., developing methods for handling larger, modular systems), and verification of Livingstone failure models in a closed loop.
- Feedback control systems are an important component in most complex machinery (e.g., aircraft). Classical control systems, however, fail when the underlying characteristics of the plant change. Here, neural network based controllers have been developed to recognize such a change (e.g., a broken wing-tip or a stuck rudder) and to automatically adapt the control system accordingly. For such systems (e.g., F15-Active), verification and certification is a central point when such systems are to be used in manned aviation. In one project within this sub-area, we are developing a software process guide and research on advanced methods to ensure that the neural network always stays within its limits.

Program Synthesis is a technique which automatically generates running code from a compact, high-level specification. This specification is *automatically* transformed into executable code (e.g., C or C++) using a large body of background knowledge, whereby the correctness of the code is always ensured. Thus, a synthesis system can be seen as a very sophisticated, knowledge-based, correct compiler. In this area, we are developing world-class program synthesis tools in the following application domains:

- *AutoBayes* is a tool for the automatic generation of complex data analysis algorithms (currently up to 1200 lines of C++ code) from compact and high level specifications. The schema-based synthesis is based upon Bayesian networks.
- *Amphion/NAV* is capable of automatically synthesizing C++ code for state estimation (e.g., for aircraft or spacecraft) using Kalman filters. The system uses an automated theorem prover and can produce extensive, hyperlinked documentation explaining all parts of the synthesized code.
- *Synthesis of UML designs*. In this project, we have developed a prototypical tool to generate UML statechart designs from requirements in the form of sequence diagrams.

Object Oriented Frameworks. The development of distributed software applications poses considerable challenges for the software designer. The main activity of this task is the development of a framework to simplify the creation of distributed applications, using techniques

from aspect-oriented programming. This work is being applied within DARWIN and the NASA-wide Intelligent Synthesis Environment.

The RIACS area of software engineering is performing important and NASA relevant research work. For the future, it is anticipated that RIACS' software engineering area and its importance within NASA will grow. Size, functional complexity, and criticality of software developed within NASA and for NASA will increase tremendously in order to meet ambitious mission goals with tight mission budgets. In order to prevent mission failures that can lead to loss of scientific data or, in the extreme case, loss of human life, the issue of producing high quality, highly reliable code will become more and more important. The RIACS software engineering area can and will play a pioneering role in addressing and solving these problems. With world-class basic research and NASA-relevant case studies, the group is developing techniques and tools which, together with the group members' experience, will make a huge impact on how software is developed, verified and certified at NASA.

RIACS Software Engineering Staff (as of 30 Sep 01)

Johann Schumann, Associate Director

Robert Filman

Bernd Fischer

Dimitra Giannakopoulou

Charles Pecheur

Grigore Rosu

Willem Visser

II RIACS Projects During FY2001

NASA Ames has identified three cornerstones of IT research necessary to meet the future challenges of NASA missions:

- Automated Reasoning for Autonomous Systems
- Human-Centered Computing
- High Performance Computing and Networking

RIACS research focuses on all three of these areas, as well as collaborating with NASA scientists to apply IT research to a variety of NASA application domains. Research projects and the overall RIACS program are regularly reviewed by an eminent Science Council. See Section IV.F for a list of current Science Council members.

II.A *Automated Reasoning for Autonomous Systems*

Deep space exploration requires significant advances in artificial intelligence to support the needed capabilities for autonomous systems. RIACS scientists and visitors have been collaborating with NASA researchers in a number of areas, as described in the following sections.

II.A.1 Automated Software Engineering

II.A.1.a Task Summary and Overview

The main objective of this task in verification and validation (V&V) is to improve the reliability of software developed at NASA, which in turn will reduce the risk of mission failure. A second (and often equally important) goal is to improve software development by employing techniques from theoretical computer science, specifically Formal Methods, to reduce software development costs.

In order to accomplish these goals we are investigating the use of model checking to automatically analyze either software already in use at NASA, or new systems under development. Specifically we are analyzing autonomous systems currently being developed at NASA Ames and JPL on both the architectural and code level as well as avionics software systems for both space flight and commercial aviation.

Under this task we have been one of the pioneering research groups applying model checking to real software - a field that has been flourishing the last couple of years. Some of our most notable successes have been finding errors in the Remote Agent autonomous system before and after its space flight (as part of NASA's Deep-Space 1 mission) and rediscovering a known problem in the DEOS real-time operating system used in certain business aircraft. In both cases we applied model checking directly to the code for these systems, hence showing the viability of this approach.

II.A.1.b RIACS Staff

Dimitra Giannakopoulou

SeungJoon Park (until July 2001)
Charles Pecheur
Grigore Rosu
Johann Schumann
Willem Visser

Visiting Staff

Alex Groce (CMU PhD Student)
Flavio Lerda (CMU PhD Student)

II.A.1.c Project Description

Several efforts have been undertaken under this task as follows:

II.A.1.c.i Java PathFinder (JPF)

JPF is a model checker for Java programs and is based on an in-house Java Virtual Machine (JVM) developed by members of the V&V task. JPF can analyze Java programs for deadlocks, assertion violations, and properties specified in linear-time temporal logic (LTL). JPF was released for world-wide use in February 2001 and since then has been downloaded by approximately 40 institutions. JPF has been used to discover a number of very subtle flaws in Java programs, most notably, it found the timing error in a Java version of the DEOS real-time operating system used in certain business aircraft. Besides the core system this project covers a number of other research areas: predicate abstraction, environment generation, heuristic search algorithms, etc.

II.A.1.c.ii Specification Centered Testing

The goal of this recently started project (jointly with Mats Heimdahl from the University of Minnesota) is to investigate the use of model checking of requirement specifications in order to do test-case generation. The novelty here is the use of test-coverage criteria as properties for the model checker - the model checker refutes the claim that a certain coverage cannot be achieved by giving a trace that will achieve the coverage. This trace can then be used to generate a test-case that, when used on the full system, will hopefully achieve the required coverage.

II.A.1.c.iii Human Computer Interaction Finding Automation Surprises

This joint project with Human Factors experts from NASA Ames will investigate the use of JPF to find automation surprises in prototype Java implementations of autopilots. In a preliminary study we have show how to generate a program to be checked by JPF from an actual autopilot user-interface; furthermore a notation for describing pilot actions and the model the pilot uses to think about the state of the automation (known as the pilot's mental model) was developed. These three components were then combined to find a previously known automation surprise automatically with JPF. In the next stages of the project we will attempt to do analysis of the actual autopilot displays to detect possible problems where the displays are inadequate to show mode changes to

the pilot. This will allow autopilot designers to interactively change their designs and run JPF to tell them about potential flaws, without having to run costly simulations with real pilots, etc.

II.A.1.c.iv System Level Verification Technology for Autonomy Software

Investigation of techniques that enable system-level verification of autonomous software. This is a basic research project that looks into two types of technologies for achieving its goals: compositional incremental verification techniques and software architectures. The main technical issues that must be resolved in this context are:

- How to decompose properties of a system in terms of properties of its components. We are particularly interested in identifying properties expected of components when specific architectural choices are made. In addition to that, the idea is to investigate what architectures facilitate modular (hence more scalable) verification.
- How to constrain the behavior of a component based on its environment (environment generation); this is useful for restricting the state-space of a component when verified in isolation, but it is also typically necessary for proving properties expected of the component in the context of the system.
- How to provide support for correct assume/guarantee style of reasoning. The focus here is to provide flexible assume/guarantee rules for guiding the designer to avoid incomplete proofs, or proofs that erroneously involve circularities.

II.A.1.c.v Verification of Neural Networks

- VeriConN - Verification of Controllers based on Neural Networks (IS): This project has started in spring 2001 and aims at the development of methods and techniques for the quality analysis of neural networks. In collaboration with Don Soloway (Code IC) and Atul Kelkar (Univ. of Iowa) we perform research on advanced NN testing and dynamic monitoring of the neural network (using confidence measures).
- On-line Learning Neural Network Flight Controller Demonstration: This project (Dryden, ISR, Ames) implements, certifies, and prepares an adaptive, NN-based flight controller for flight-tests on an F-15 Active. Our role (with Mark Boyd and Bojan Cukic) is to provide a software process guide, specifically focusing on design and development requirements for neural networks based software.

II.A.1.c.vi V&V of Model-Based Autonomy Software

The goal of this effort is to apply verification and validation (V&V) techniques to autonomous software, and more particularly to the Livingstone system from Ames. Charles Pecheur is the software project leader and only ASE staff on the Livingstone project, done in collaboration with Carnegie Mellon University (CMU), the Autonomy group at Ames, and KSC. This project is structured in two phases, centered on the development of two tools:

- MPL2SMV, a compiler that translates Livingstone models so they can be verified using the SMV model checker.

- Livingstone PathFinder (LPF), a verification tool that applies a model checking algorithm to drive the execution of the real Livingstone program, placed in a simulated environment.

Since June 2001, Charles Pecheur is also involved in a project on Integrated Vehicle Health Maintenance (IVHM) for the 2nd Generation Reusable Launch Vehicle (RLV), headed by Northrop Grumman. He leads a task whose goal is to provide recommendations for V&V of IVHM, including a Livingstone-based diagnosis system.

II.A.1.c.vii Lightweight Formal Methods Runtime Verification and Certification

A recent research direction is focused on lightweight formal methods, more precisely on runtime verification and certification. The goal is to avoid the usually worse than exponential complexity of heavyweight formal methods such as theorem proving and model checking. Runtime verification is concerned with monitoring the execution of a program and detecting either errors that occurred and need to be recovered or potential errors that did not occur during the monitored execution but could occur in other possible executions. Certification, or domain-specific extended type checking, is concerned with statically verifying various domain dependent safety policies, such as metric unit consistency or coordinate frame consistency. Of recent interest is the combination of runtime verification and static analysis of programs.

II.A.1.d Accomplishments during FY2001

II.A.1.d.i JPF and related

- Willem Visser (RIACS) and Klaus Havelund (Kestrel Technologies) were awarded a “Disclosure of Invention and New Technology (including Software)” (ARC-14599-1) by the NASA Technology Office for the Java PathFinder model checker.
- Java PathFinder has been released world-wide, and has already been downloaded by approximately 40 institutions. It has also attracted a number of organizations that have entered into agreement with NASA to help further develop the tool (these include: University of Minnesota, Stony Brook, Kansas State, University of Liverpool and Carnegie Mellon University).
- Parallel and Distributed versions of JPF have been developed that run on a Silicon Graphics Origin 2000.
- Heuristic search capabilities have been added to JPF, that allows it to use, for example, test-coverage criteria to guide the search space. Techniques from search-theory, such as queue size limiting has also been found to be extremely valuable in focusing the search for errors. With heuristics, previously undetected faults can often be found almost instantly.
- A pilot study in the use of JPF to find automation surprises was successfully completed. We were able to use JPF to find the well-known “kill-the-capture” automation surprise in the pitch autopilot of an MD-88 by analyzing the autopilot tutor for this aircraft developed at NASA. As part of this project a regular expression language was developed that, in the future, can be used to define model checking environments for use when checking Java programs with JPF.

II.A.1.d.ii System Level Verification Technology for Autonomy Software

- Remote Agent case study: A case study of the Remote Agent has been performed, where several aspects of compositionality were applied. This case study has been a great help in identifying how properties can be decomposed, in experiencing what type of support one would need so as to perform this style of reasoning, and what the role of architecture can be. The results were extremely encouraging. All properties of interest were decomposed; we managed to detect not only all the errors that had been detected in a previous non-compositional model-checking attempt, but also two additional ones. The latter were problems related to the architectural design of the system, rather than associated with the specific application. This is very important, since it confirms that architectural choices often dictate specific properties for the components that participate in these architectures, as well as the types of reasonable assumptions that can be made in such environments. These properties and assumptions could be general and reusable.
- Rover System: We have made progress with understanding the architecture of the Rover System, and with detecting some architectural issues that we wish to pursue, related to the way components communicate.
- Linear Temporal Logic to automata translator: A very efficient translator has been developed. The translator constructs automata from LTL specifications. These automata can be used both for model checking LTL in the context of Java Pathfinder (JPF), and for generating environments for compositional verification.

II.A.1.d.iii Autonomy Related

Accomplishments related to MPL2SMV are as follows:

- Support and guidance to the In-Situ Propellant Production (ISPP) team at KSC. This team uses Livingstone to control a fuel production unit for Mars missions, and is using MPL2SMV to verify their ISPP models. There are weekly teleconferences with Peter Engrand, who is in charge of the verification part. This year has seen the migration to a new ISPP technology (Reverse Water Gas Shift, RWGS) with a corresponding new model. At least two confirmed modeling errors have been unveiled using the verification tools.
- Development and experimentation with variable dependency properties. We have defined a way to verify functional dependency between model variables using the SMV model checker. Improper specification of such dependencies is a common source of error in Livingstone models. In collaboration with Peter Engrand, we used this to demonstrate and analyze a known bug in the ISPP model.
- Verification of the full RWGS model. We also had to help the KSC team to tackle with the most complete version of their ISPP model. Doing so required some changes in the model to eliminate unsupported features, an upgrade of MPL2SMV to support a new Livingstone language feature, and using a new optimized version of SMV (due to Bwolen Yang), as the standard version could not handle the size of the model. The latest model reports a size of 1055 states.

II.A.1.d.iv Livingstone PathFinder

- **First Demonstration:** In September 2000, we obtained a first proof-of-concept demonstration of the LPF closed-loop verification tool for Livingstone. This demonstration shows a Livingstone engine used to simulate a Livingstone model (but not doing fault diagnosis). Alternative scenarios combining commands and faults are automatically explored.
- **Cooperation with Livingstone Team:** We had to adjust the verification tool to changes in the interface in new versions of the Livingstone system. We have been working with the Livingstone development team to make sure that the features needed for closed-loop verification be added and made accessible to the verification environment.
- **Complete demonstration:** The complete LPF tool is still in progress. A first running version is expected by the end of 2001.

II.A.1.d.v V&V of IVHM

- The work on this new project started in mid-July 2001. Stacy Nelson (CSC) is the main contributor to this task, under project leader supervision. Three reports are due in the baseline period ending March 2002; we have a complete draft for the first one and are initiating work on the second one.

II.A.1.d.vi Runtime Verification and Certification

- We are developing a system called PathExplorer which implements the state of the art in runtime verification algorithms, that is, algorithms that detect potential deadlocks and data races in programs, and also algorithms that verify execution traces against temporal logic requirements. A concrete version of PathExplorer, called Java PathExplorer, has already been implemented and tested on a case study finding a potential deadlock in the K9 rover. The system is designed in such a way that the user can easily add new logics for requirements specification and new algorithms for error pattern analysis.
- We have implemented a coordinate frame safety certifier which can be used to find inconsistencies in astronomical programs, such as, for example, in calculating the distance between the points specified by two vectors which are not represented in the same coordinate system. Many of the programs synthesized by the Amphion/NAIF system were certified using this certifier and, unexpectedly, an error was found in Amphion/NAIF. The certifier is completely automatic and its complexity is quadratic in the size of the certified program, so it scales up well. It is rarely the case that programs using the NAIF library have more than 100 lines of code (because of the substantial functionality of the NAIF component library), but we were able to certify synthetic programs of 1,000 lines of code in about 1 second.

II.A.1.e Workshops Organized

- Dimitra Giannakopoulou - Organization of an OOPSLA 2001 (ACM Conference on Object Oriented Programming, Systems, Languages and Applications) workshop on specification and verification of component-based systems.
- Willem Visser, Reid Simmons (CMU), and Charles Pecheur organized a two-day workshop on “Verification and Validation of Autonomous and Adaptive Systems”

sponsored by RIACS, in December 2000. The first day had five speakers present different real systems and discuss their V&V issues, while the second day was devoted to open discussions in small breakout groups. We edited a report summarizing the discussions that took place, which is to be published in AI Magazine and also available on the web. The report was presented as a RIACS Seminar and at a RIACS Science Council Meeting. The workshop website is at <http://ase.arc.nasa.gov/vv2000/>.

- Lina Khatib (Kestrel) and Charles Pecheur co-organized a symposium on “Model-based Validation of Intelligence” as part of the AAAI Spring Symposium Series in March 2001. We provided the technical content (announcement, reviews and selection of articles, final program) while AAAI provided the logistics (rooms, registration, etc.). A short report is due to appear in AAAI Magazine. We have managed the web pages for this event, including a repository of contributions from participants (<http://ase.arc.nasa.gov/mvi/>).
- Willem Visser, John Penix (NASA Ames) and Nigel Tracy (University of York, UK) organized the 2nd WAPATV workshop at ICSE’01 in Toronto, Canada, 13 May 2001.
- Willem Visser and Scott Stoller (Stony Brook) organized the Workshop on Software Model Checking in Paris, France, 23 July 2001.
- Klaus Havelund and Grigore Rosu organized the First CAV Workshop on Runtime Verification (CAV’01), Paris, France.

II.A.1.f Problems encountered

Export control issues with MDS. To take into account systematic attempts at capturing architectural choices and concerns for good/reusable design of autonomous systems, we have pursued collaboration with JPL’s Mission Data Systems (MDS) team. However, the collaboration is currently stuck due to export control issues.

Due to the (partly unexpected) kick-off of the new project on V&V of IVHM in June, Charles Pecheur has faced significant additional managerial duties that have delayed progress on his other project, more specifically on the development of the Livingstone Pathfinder program.

II.A.1.g Publications and Presentations during FY2001

II.A.1.g.i Publications

1. Reid Simmons, Charles Pecheur, Grama Srinivasan. Towards Automatic Verification of Autonomous Systems. In: Proceedings of the 2000 IEEE/RSJ International Conference on Intelligent Robots and Systems, IEEE, 2000.
2. Charles Pecheur, Willem Visser, Reid Simmons. RIACS Workshop on the Verification and Validation of Autonomous and Adaptive Systems. Conference report, to appear in AI Magazine Journal. Also available as NASA/TM-2001-210927, August 2001, and RIACS TR 01-20, June 2001.
3. Charles Pecheur. Verification and Validation of Autonomy Software at NASA. NASA/TM 2000-209602, August 2000.
4. Charles Pecheur, Reid Simmons and Peter Engrand have contributed a chapter for a book based on Formal Aspects of Agent-Based Systems, following on a NASA workshop at Goddard in April 2000. That book is due to come out in 2002.

5. Dimitra Giannakopoulou and John Penix, "Component Verification and Certification in NASA Missions". In Proceedings of the 4th ICSE Workshop on Component-Based Software Engineering: Component Certification and System Prediction, Toronto, Canada, May 2001.
6. Dimitra Giannakopoulou and Klaus Havelund, "Automata-Based Verification of Temporal Properties on Running Programs", to be presented at the 16th IEEE International Conference on Automated Software Engineering (ASE'2001), San Diego, CA.
7. Dimitra Giannakopoulou and Klaus Havelund, "Runtime Analysis of Linear Temporal Logic Specifications", RIACS Technical Report 01.21.
8. G. Brat (Kestrel Tech.), K. Havelund (Kestrel Tech.), S. Park, W. Visser. Java PathFinder - A second generation of a Java model checker. Proceedings of the Workshop on Advances in Verification (WAVE00), Chicago, July 2000.
9. W. Visser, S. Park and J. Penix (NASA Ames). Applying Predicate Abstraction to Model Check Object-Oriented Programs. Proceedings of the 3rd ACM SIGSOFT Workshop on Formal Methods in Software Practice. Portland, August 2000.
10. W. Visser, K. Havelund (Kestrel Tech.), G. Brat (Kestrel Tech.) and S. Park. Model Checking Programs. Proceedings of the 15th International Conference on Automated Software Engineering (ASE00), September 2000. Nominated for best-paper (insiders revealed it came in 2nd, although this is not official).
11. C. Pasareanu (Kansas State), M. Dwyer (Kansa State), W. Visser. Finding Feasible Counter-examples when Model Checking Abstracted Java Programs. Proceedings of the International Conference on Tools and Algorithms for Construction and Analysis of Systems. Published in Lecture Notes for Computer Science volume 2031. Genoa, Italy. April 2001.
12. M. Dwyer, J. Hatcliff, R. Joehanes, S. Laubach, C. Pasareanu, Robby (all Kansas State), W. Visser, H. Zheng (Kansas State). Tool-supported Program Abstraction for Finite-state Verification. Proceedings of the International Conference on Software Engineering, Toronto, Canada, May 2001.
13. F. Lerda and W. Visser. Addressing Dynamic Issues of Program Model Checking. Proceedings of the 8th International SPIN Workshop. Published in Lecture Notes in Computer Science volume 2057. Toronto, May 2001.
14. M. Heimdahl, S. Rayadurgam (both Univ. of Minnesota) and W. Visser. Specification Centered Testing. Proceedings of the Second International Workshop on Automated Program Analysis, Testing and Verification. Toronto, May 2001.
15. J. Penix (NASA Ames) and W. Visser. Coverage Metrics for Model Checking. Proceedings of the Second International Workshop on Automated Program Analysis, Testing and Verification. Toronto, May 2001.
16. W. Visser, K. Havelund (Kestrel Tech.), G. Brat (Kestrel Tech.), S. Park, F. Lerda. Model Checking Programs. Extended Journal version of (9), invited for publication in the Automated Software Engineering Journal. To appear.
17. G. Brat and W. Visser. Combining static analysis and model checking for software analysis. Proceedings of the 16th International Conference on Automated Software Engineering (ASE01), to appear November 2001.

18. Scott Stoller and Willem Visser. Software Model Checking 2001 First CAV Workshop on Software Model Checking (SoftMC'01), Paris, France Electronic Notes in Theoretical Computer Science, 55(3), 2001
19. Joseph Goguen and Grigore Rosu. Institution Morphisms. Formal Aspects of Computing, to appear
20. Grigore Rosu. Axiomatizability in Inclusive Equational Logic. Mathematical Structures in Computer Science, to appear
21. Grigore Rosu. Equational Axiomatizability for Coalgebra. Theoretical Computer Science, Volume 260, Number 1-2, 2001
22. Klaus Havelund and Grigore Rosu. Runtime Verification 2001. First CAV Workshop on Runtime Verification (RV'01), Paris, France Electronic Notes in Theoretical Computer Science, 55(2), 2001
23. Klaus Havelund, Scott Johnson and Grigore Rosu. Specification and Error Pattern Based Program Monitoring. European Space Agency Workshop on On-Board Autonomy, Noordwijk, Holland 17-19 October 2001
24. Klaus Havelund and Grigore Rosu. Monitoring Programs using Rewriting. Automated Software Engineering 2001 (ASE'01), San Diego, California Institute of Electrical and Electronics Engineers Computer Society
25. Michael Lowry, Thomas Pressburger and Grigore Rosu. Certifying Domain-specific Policies. Automated Software Engineering 2001 (ASE'01), San Diego, California Institute of Electrical and Electronics Engineers Computer Society
26. Grigore Rosu. Complete Categorical Equational Deduction. Computer Science Logic (CSL'01), Paris, France, 10-13 September 2001 Lecture Notes in Computer Science 2142
27. Bernd Fischer and Grigore Rosu. Interpreting Abstract Interpretations in Membership Equational Logic. International Workshop on Rule-Based Programming (RULE'01) Electronic Notes in Theoretical Computer Science, 59(4), 2001
28. Klaus Havelund and Grigore Rosu. Monitoring Java Programs with Java PathExplorer First Workshop on Runtime Verification (RV'01), Paris, France Electronic Notes in Theoretical Computer Science, 55(2), 2001
29. Bernd Fischer, Tom Pressburger, Grigore Rosu and Johann Schumann. The AutoBayes Program Synthesis System - System Description Symposium on the Integration of Symbolic Computation and Mechanized Reasoning (CALCULEMUS 2001), Siena, Italy
30. Grigore Rosu and Joseph Goguen. Circular Coinduction. International Joint Conference on Automated Reasoning (IJCAR'01), Siena, Italy Short paper.
31. Klaus Havelund and Grigore Rosu. Java PathExplorer - A Runtime Verification Tool. Symposium on Artificial Intelligence, Robotics and Automation in Space (ISAIRAS'01), Montreal, Canada, 18-22 June 2001
32. Klaus Havelund and Grigore Rosu. Synthesizing Dynamic Programming Algorithms from Linear Temporal Logic Formulae. RIACS Technical Report TR 01-15, May 2001
33. Klaus Havelund and Grigore Rosu. Testing Linear Temporal Logic Formulae on Finite Execution Traces. RIACS Technical Report TR 01-08, May 2001
34. Lutz Hamel and Grigore Rosu. A Hidden Approach to Program Behavior, Translation and Optimization Submitted to POPL'02

II.A.1.g.ii Presentations

1. Charles Pecheur. The Automated Software Engineering group. Presentation at INRIA Rhone-Alpes, France, 11 September 2000.
2. Charles Pecheur, Willem Visser. Model Checking for Software. Tutorial presented at the ASE'00 conference, Grenoble, France, 12 September 2000.
3. Charles Pecheur. Verification of Intelligent Software. Presentation at NASA Kennedy Space Center, Florida, November 2000.
4. Charles Pecheur, Willem Visser. Report on RIACS Workshop on the Verification and Validation of Autonomous and Adaptive Systems (Asilomar, December 2000). Presentation as a RIACS Seminar at NASA Ames, Moffett Field, California, February 2001. Also presented at the RIACS Science Council, June 2001.
5. Charles Pecheur. Verification and Validation of Model-Based Autonomous Software. Presentation at the OSMA SAS'01 Symposium, Morgantown, WV, 6 Sept 2001.
6. Giannakopoulou D., and Penix J., "Component Verification and Certification in NASA Missions". 4th ICSE Workshop on Component-Based Software Engineering: Component Certification and System Prediction, Toronto, Canada, May 2001.
7. Giannakopoulou, D. and Havelund, K., "Runtime Analysis of Linear Temporal Logic Specifications", RIACS Technical Report 01.21.
8. Giannakopoulou, D. May 31 2001, RIACS seminar on "Reasoning about Large Systems in a Compositional Way".
9. Giannakopoulou, D. August 23, 2001. Seminar, Computer Science Department, University of Oregon at Eugene, "Reasoning about Large Systems in a Compositional Way".
10. Willem Visser. Java PathFinder - A second generation of a Java model checker. Paper presentation at WAVE00, Chicago, July 2000.
11. Willem Visser. Model Checking Software. Tutorial at ASE00, Grenoble, France September 2000.
12. Willem Visser. JPF Demo and short presentation. INRIA, Grenoble, France. September 2000.
13. Willem Visser. Invited JPF Demo. ASE00, Grenoble, France. September 2000.
14. Willem Visser. Model Checking Programs. Paper presentation at ASE00. Grenoble, France.
15. Willem Visser. Model Checking Programs. Invited by Prof Ed Clarke to present current work in software model checking, December 2000.
16. Willem Visser. Java Model Checking. Invited Presentation at National Security Agency. Baltimore, March 2001.
17. Willem Visser. JPF demo. Invited demonstration at NSA. March 2001.
18. Willem Visser. RIACS Workshop on V&V of Adaptive Systems. RIACS Seminar jointly presented with Charles Pecheur and Johann Schumann, 22 February 2001.
19. Willem Visser. University of Minnesota IS-project kick-off meeting. JPF presentation and demonstration. 25 June 2001.
20. Willem Visser. Honeywell Technology Center. Minneapolis. JPF presentation and demonstration. 27 June 2001.
21. Willem Visser. Microsoft Workshop. Leavenworth, Washington. Java Model Checking. 15 August 2001.

22. Willem Visser and Guillaume Brat. Using Model Checking for finding Automation Surprises. Human Computer Interaction, IS Program review. NASA Ames, 18-19 September 2001.
23. Grigore Rosu. Hidden Logic, Stanford University (Zohar Manna's group), California, USA, 19 January 2001.
24. Klaus Havelund and Grigore Rosu. Monitoring Java Programs with Java PathExplorer First Workshop on Runtime Verification (RV'01), Paris, France
25. Grigore Rosu. Interpreting Abstract Interpretation in Membership Equational Logic International Workshop on Rule-Based Programming (RULE'01)
26. Grigore Rosu. Complete Categorical Equational Deduction Computer Science Logic (CSL'01), Paris, France, 10-13 September 2001

II.A.1.h Future Plans

II.A.1.h.i System Level Verification Technology for Autonomy Software

- To experiment with various systems, and identify architectural issues that can be verified on system components. Ideally, MDS would be one of those systems.
- To demonstrate the impact of compositional techniques on a running project - probably the Rover Executive. The Executive is to be extended in various directions, including dynamic plan updates, and concurrent task execution (probably at a later stage). A goal is therefore to closely participate in the correct design of these new features.
- Introduction of compositional verification capabilities to JPF, which is the ASE group's contributed tool to software verification.

II.A.1.h.ii V&V of Model-Based Autonomy Software

- The end of this fiscal year corresponds to the end of a three-year project on V&V of Model-Based Autonomy Software. In FY 02, Charles Pecheur plans to devote more time to writing and submitting papers on his current research.
- Continue support and development of the Livingstone PathFinder tool as part of a Livingstone-centered project led by Mark Shirley (ARA group).
- Continuing support and development the MPL2SMV tool will depend on available resources. Possible directions are the migration to the new Livingstone modeling language, and experiments with SAT-based model checking that could allow scaling up to even larger models.
- The V&V of IVHM project baseline period concludes with a formal review in February 2002, that will affect following phases. We will continue as the Ames lead for the V&V tasks assuming the tasks are continued. Future work involves integrating the V&V tools we have developed into the IVHM design environment.
- We are in the process of establishing a Memorandum of Understanding with Interface Control Systems, Inc. (ICS), a company that develops design tools for diagnosis systems based on Livingstone. Our goal is to integrate the tools that we have been developing into the ICS toolset.

II.A.1.h.iii JPF related

- We will continue support of the JPF model checker for the growing number of installations around the world.
- In collaboration with students from Carnegie Mellon University we will extend JPF with a number of new capabilities including improved heuristic search capabilities and parallel algorithms.
- We will enhance the capabilities of JPF as an advanced testing tool, by aligning it more closely with testing practice. Specifically, we will be improving the test-case generation capabilities of JPF and the calculation of coverage measures.
- A C/C++ front-end to the JPF model checker will be developed in conjunction with Apogee.

II.A.1.h.iv Runtime Verification and Certification

- Regarding Runtime Verification, we intend to develop a stable version of Java PathExplorer that can be downloaded and used by other scientists. We also work on improving deadlock and data race algorithms to issue more positive and fewer false warnings. Other monitoring logics of interest are also under investigation, such as interval logics and real time temporal logics.
- In certification there are two future research plans. One is to generalize the existing coordinate frame safety certifier to allow more complex programs with conditionals, loops and procedure calls, and the other is to develop other domain-specific certifiers using the same architecture; an immediate goal is a certifier for unit consistency.
- A longer term goal is to combine runtime verification and certification. For example, in order to keep the complexity low, one could certify (statically) only properties that can be checked in a reasonable amount of time, while the others being monitored at runtime.

II.A.2 Object-Oriented Frameworks

II.A.2.a Task Summary

The primary activity of this task is the development of a framework to simplify the creation of distributed applications. Key ideas include applying aspect-oriented programming technology to separate the specification of systematic policies from underlying functional code and developing richer mechanisms for event-based publish-and-subscribe services. This work is applicable to the development of distributed applications as the DARWIN wind-tunnel data reporting system and the NASA-wide Intelligent Synthesis Environment virtual design system.

For more information: <http://www-darwin.arc.nasa.gov>

II.A.2.b RIACS Staff

Robert Filman

II.A.2.c Project Description

NASA has the difficult problem in coordinating the activities and providing data and computational services to widely separated scientists and engineers. The primary approach to simplifying such coordination is to develop distributed software applications that allow NASA employees and contractors to share data and programs. State-of-the-art technology allows building such applications, but such application development is difficult and produces fragile, one-of-a-kind solutions. Over the past year, we have worked on developing technology to simplify the task of creating distributed applications, creating this technology in the contexts of the Intelligent Synthesis Environment, and DARWIN. The objectives in this context have been

- Working on defining and building DARWIN system.
- Working in the architectural group of the ISE project to define the ISE architecture.
- Exploring new architectures for distributed system development, primarily in the direction of Aspect-Oriented Programming Systems.
- Disseminating information on distributed computing to NASA, academic organizations and industry.

A critical issue in developing component-based and distributed systems is getting the assembled set of components to follow the policies of the overall system. To achieve goals such as reliability, availability, responsiveness, performance, security, and manageability, all system components must consistently perform certain actions. We have been developing an Aspect-Oriented Programming technology, the Object Infrastructure Framework (OIF). OIF is a CORBA centered system for achieving “ilities” in distributed systems. OIF realizes the following key ideas:

- Intercepting communications. OIF intercepts and manipulates communications among functional components, invoking appropriate services on these calls.
- Discrete injectors. Our communication interceptors, injectors, are first class objects.
- Injection by object/method. Each instance and each method on that object can have a distinct sequence of injectors.
- Dynamic injection. The injectors on an object/method are maintained dynamically and can, with the appropriate privileges, be added and removed.
- Annotations. Injectors can communicate among themselves by adding annotations to the underlying requests of the procedure call mechanism.
- Thread contexts. To allow clients and servers to communicate with the injector mechanism, the system maintains a “thread context” of annotations for threads, and copies between this context and the annotation context of requests.
- High-level specification compiler, a compiler from high-level specification of desired properties and ways to achieve these properties to default injector initializations. OIF injectors on CORBA-wrapped tools and services can be used to enforce and perform systematic services such as
 - Maintain the annotations of artifacts created by running design tools.
 - Enforce complex, not-yet-anticipated access control rules on data, particularly as contractors form federations to deal with design subproblems.
 - Enforce automatic data set transformations to translate between representations.
 - Supply alternative servers of the same service.

- Report on the status of jobs to distributed managers and debuggers.
- Support “session” environments reflecting user privileges downstream and carrying the user environment.
- Support “long-lived” transactions needed by the design process, (in contrast to “database” transactions, such as bank account updates and airline reservations.)
- Obtain and assure the appropriate versions of datasets.
- Provide software redundancy and mobility, enabling moving computations and data for increased efficiency.

We have also been working with other Code IC staff on the development of the DARWIN system (DARWIN is a distributed system for the delivery and analysis of wind-tunnel data) and with the Intelligent Synthesis Environment (ISE) project to define the distributed ISE architecture.

II.A.2.d Accomplishments during FY2001

- Designed the server architecture for DARWIN 3. The current architecture is primarily a three-tier model, where the business logic of the middle tier includes checking security permissions and data synthesis, and forwarding data to a fat client.
- Developed the underlying theoretical foundations of Aspect-Oriented Programming
- Designed the application of the OIF mechanisms to ISE, and generated the requirements for the tool matchmaking facility for ISE..

II.A.2.e Problems Encountered and Possible Resolution

The ISE project was terminated. Will need to work with the successor projects to see how we can be helpful.

II.A.2.f Publications and Presentations during FY2001

II.A.2.f.i Publications

35. Robert E. Filman, Stu Barrett, Diana Lee, and Ted Linden, “Inserting Ilities by Controlling Communications,” Communications of the ACM, in press.
36. J. D. Walton, R. E. Filman, C. Knight, D. J. Korsmeyer, and D. Lee. D3: A Collaborative Environment for Aerospace Design. Workshop on Advanced Collaborative Environments, San Francisco, August 2001. <http://horus.riacs.edu/documents/data/00/00/00/49/index.html>
37. Robert E. Filman, “A Software Architecture for Intelligent Synthesis Environments,” in Proc. 2001 IEEE Aerospace Conference, Big Sky, Montana, March 2001. <http://horus.riacs.edu/documents/data/00/00/00/44/index.html>
38. Robert E. Filman, “What Is Aspect-Oriented Programming, Revisited,” Workshop on Advanced Separation of Concerns, ECOOP 2001, Budapest, June 2001. <http://horus.riacs.edu/documents/data/00/00/00/48/index.html>
39. Robert E. Filman and Daniel P. Friedman, “Aspect-Oriented Programming is Quantification and Obliviousness,” Workshop on Advanced Separation of Concerns,

- OOPSLA 2000, October 2000, Minneapolis.
<http://horus.riacs.edu/documents/data/00/00/00/46/index.html>
40. Robert E. Filman and Diana D. Lee, "Redirecting by Injector," in Proc. 21st IEEE Intl. Conf. on Distributed Computing Systems, Vol 2 (Workshops) International Workshop on Distributed Dynamic Multiservice Architectures, Phoenix, Arizona, April 2001, pp.141-146. <http://horus.riacs.edu/documents/data/00/00/00/36/index.html>
 41. Robert E. Filman, and Diana D. Lee Managing Distributed Systems with Smart Subscriptions (brief version). Workshop on The Next 700 Distributed Object Systems, ECOOP 2001, Budapest, June 2001.
 42. Vir V. Phoha, "A Dictionary of Internet Security Terms," (Dorothy Denning, Li Gong, John McLean, Robert E. Filman, Elisa Bertino, Jeffrey Schiller, Flemming Nielson, Ejiji Okamoto, John Yesberg, Alfred Menezes, Dieter Gollmann, Csilla Farkas, S. S. Iyenger, Asok Ray, Stephen Kent, and Shashi Phoha, Editorial Board), Berlin: Springer-Verlag, in preparation.
 43. Tzilla Elrad, Robert Filman and Atef Bader, Aspect-Oriented Programming (Guest Editors Introduction), Communications of the ACM, Vol 44, No. 10, October 2001, in preparation.
 44. Robert E. Filman, "Medicine on the Net: From Isolation to Universal Connectivity," (Editor's Introduction) IEEE Internet Computing, Vol. 5, No. 3, May 2001, pp. 40-41.
 45. Robert E. Filman, "Embedded Internet Systems Come Home," (Editor's Introduction) IEEE Internet Computing, Vol. 5, No. 1, January 2001, pp. 52-53.

II.A.2.f.ii Presentations

27. "The Object Infrastructure Framework: An Aspect-Oriented Programming System for Distributed Computing," University of Michigan, October, 2000.
28. Resource Location and Allocation Intelligent Synthesis Environment Conference, Pasadena, January 2001.
29. Panel, "The Next 700 Distributed Object Systems," European Conference on Object-Oriented Programming, Budapest, June 2001.

II.A.2.f.iii Activities

- Associate Editor-in-Chief, IEEE Internet Computing.
- Guest Editor, October 2001 Communications of the ACM Special Section on Aspect Oriented Programming
- Founding Chair, Steering Committee, International Conference on Aspect-Oriented Software Development
- Organizing committee, OOPSLA 2001 Workshop on Engineering Complex Object-Oriented Systems for Evolution
- Organizing committee, OOPSLA 2001 Workshop on Advanced Separation of Concerns.
- Program Committee, Workshop on Aspect Oriented Programming for Distributed Computing Systems, 22nd International Conference on Distributed Computing Systems (ICDCS 2002).
- Session chair, International Workshop on Distributed Dynamic Multiservice Architectures, ICDCS 2001, Phoenix, Arizona, April 2001.

- Editorial Board, The International Journal of Artificial Intelligence Tools. Publications.
- Program Committee, International Conference on Aspect-Oriented Software Development 2002.

II.A.2.g Future Plans

- Enhance the theoretical basis of aspect-oriented computing, extending OIF to illustrate points about AOP.
- Apply these mechanisms to a NASA application.
- Bring the development of Darwin 3 to a successful completion, and discover other applications of the technology.

II.A.3 Automated Software Synthesis

II.A.3.a Task Summary

This research task in automated software engineering is primarily concerned with the development of advanced tools for the automatic generation of reliable, high-quality code from a high-level specification. Software synthesis is based upon formal approaches and thus enables the justified generation of programs. In this task, research focuses on the development of synthesis tools and approaches for several NASA-relevant domains, such as science data-analysis, spacecraft and aircraft state-estimation, and the generation of UML designs.

II.A.3.b RIACS Staff

Bernd Fischer
Grigore Rosu
Johann Schumann
Mahadevan Subramaniam (through March 2001)

Visiting Staff

Ralph Benzinger, SSRP (2000 Continuation Award)
Kate Mullen, SSRP
Michael Whalen, SSRP

II.A.3.c Project Description

Several efforts have been undertaken under this task as follows:

II.A.3.c.i AutoBayes Automatic Synthesis of Data Analysis Programs

In this project (collaborating with Tom Pressburger), a tool for the automatic synthesis of data analysis programs is developed. AutoBayes takes a compact specification of a statistical model and produces executable C++ code (currently up to about 1200 lines). The statistical models are based upon Bayesian networks.

II.A.3.c.ii Amphion/NAV Automatic Synthesis of Software for State Estimation

This project (collaborating with Guillaume Brat, Mike Lowry, John Penix, Tom Pressburger, Phil Oh, Peter Robinson, Jeffrey van Baalen, and Jonathan Whittle) is concerned with the automatic generation of software for the position estimation with Kalman filters. Based upon a specification of the sensors and their geometric configuration, code and explanations are generated with an automated theorem prover.

II.A.3.c.iii Synthesis of UML designs from requirements (PecSee)

The Unified Modeling Language (UML) has become a de-facto standard for the design and development of object oriented software. Work done in this project (with Jonathan Whittle and Phil Oh) supports a highly iterative software process by automatic generation of designs (statecharts) from requirements (sequence diagrams).

II.A.3.d Accomplishments during FY2001**II.A.3.d.i AutoBayes Automatic Synthesis of Data Analysis Programs**

In FY 01, work continued on the automated synthesis of data analysis software. The AutoBayes system now works end-to-end for the first NASA application, the detection of change points in Gamma Ray Burst data, i.e., AutoBayes generates fully documented code from the specification and runs the code on the previously collected science data. This work is done in collaboration with J. Scargle, Code SST. A number of additional problems from the UCI Machine Learning Repository benchmark collection was also successfully handled by AutoBayes (work done by K. Mullen). The schema library was extended by the schemas necessary for the changepoint detection and the other problems.

Throughout the year the logical core of AutoBayes was extended and improved. Compared to last year, the speed of the system was increased by a factor of approximately 15. AutoBayes now generates up to 250 lines of documented C++ code per second. Some initial results were achieved for code optimization and code certification. AutoBayes includes a new high-level common subexpression elimination; moreover, it can now exploit domain-specific and model-specific information for optimization, leading to better optimization results than a traditional compiler could achieve.

II.A.3.d.ii Amphion/NAV Automatic Synthesis of Software for State Estimation

In this project, a major milestone was accomplished in January 2001. We were able to successfully demonstrate the running Amphion/NAV system to the L2 program manager. This system is capable of generating more than 600 lines of C++ code from a graphical specification, describing the sensors and their geometric configuration. Johann Schumann has implemented a simulation harness which allows to run the synthesized code on artificial data. With one underlying domain-theory (in first-order logic) we have been able to synthesize code for various sensor/architecture variants (e.g., INS with 2 DME, INS with 2 DME and baro-altimeter, stand-alone GPS, INS + GPS).

II.A.3.d.iii Synthesis of UML designs from requirements (PecSee)

During this year, the project team (Jonathan Whittle, Phil Oh, and Johann Schumann), worked on various aspects of the synthesis system, in particular on aspects of the “backwards direction”

(checking and updating the requirements when a statechart has been modified), generation of hierarchical structures, and the use of this approach to automatic debugging.

II.A.3.d.iv Further Accomplishments in Program Synthesis

Substantial effort has been undertaken to decide on a common platform for the AutoBayes and Avionics synthesis projects. Reasons for that are that both approaches share many commonalities, and that the theorem prover, underlying Amphion hit scalability problems. Two alternatives were evaluated in detail: using the PROLOG platform and substantial portions of the AutoBayes system as a common platform or to implement the synthesis systems upon Maude, a rewriting system and language developed at SRI. Various experiments and discussions led to the conclusion that for purposes of building synthesis systems, PROLOG has more advantages. We therefore decided to build the synthesis systems on that platform, re-using most of the symbolic system (B. Fischer) and the code-generator (J. Schumann)

II.A.3.e Publications and Presentations during FY2001

II.A.3.e.i Publications

46. Schumann, Johann. Automated Theorem Proving in Software Engineering. Springer-Verlag, ISBN 3-540-67989-8, 2001.
47. Fischer, Bernd, Schumann, Johann, Pressburger, Tom: Generating Data Analysis Programs from Statistical Models. Proc. ICFP Workshop on Semantics, Applications and Implementation of Program Generation (SAIG), Montreal, September 2000. LNCS 1924, pp. 212-229.
48. Fischer, Bernd, Schumann, Johann: AutoBayes: A System for the Synthesis of Data Analysis Programs, NIPS*2000 Workshop on Software Support for Bayesian Analysis Systems, Breckenridge, CO, December 2000.
49. Fischer, Bernd, Rosu, Grigore: Interpreting Abstract Interpretations in Membership Equational Logic, Proc. Second International Workshop on Rule-Based Programming, also RIACS Technical Report 01.16.
50. Fischer, Bernd, Pressburger, Tom, Rosu, Grigore, Schumann, Johann: The AutoBayes Program Synthesis System, Proc. CALCULEMUS'01, pp. 168-172.
51. Fischer, Bernd, Schumann, Johann: AutoBayes: A System for Generating Data Analysis Programs from Statistical Models, under review at the Journal of Functional Programming.
52. Schumann, Johann and Peter Robinson. [] or SUCCESS is Not Enough: Current Technology and Future Directions in Proof Presentation, In Proc. Workshop on Future Directions in Automated Deduction (coll. IJCAR '2001), 2001.
53. Schumann, Johann. Automatic Synthesis of UML Designs from Requirements in an Iterative Process, Extended Abstract. Invited Talk. In Proc. Precise Modeling and Deduction (PMD'01), (coll. IJCAR '2001), 2001.
54. Jon Whittle and Schumann, Johann. Generating Statechart Designs From Scenarios. (extended version). ACM Transactions on Software Engineering and Methodology (TOSEM), invited submission, 2001.
55. Schumann, Johann and Jon Whittle. Automatic Synthesis of Agent Designs in UML. In Proc. FAABS 2000, Springer-Verlag, 2001.

56. Schumann, Johann. Automatic Debugging Support of UML Designs. In Proc. Fourth International Workshop on Automatic Debugging, 2000. (available as <http://xxx.lanl.gov/abs/cs.SE/0011017>)
57. Jon Whittle and Schumann, Johann. Generating Statechart Designs From Scenarios. In Proc. ICSE 2000, IEEE Press, 2000.

II.A.3.e.ii Presentations

30. Fischer, Bernd. AutoBayes system demonstration, RULE2000 workshop, Montreal, Canada, 9/19/00.
31. Fischer, Bernd. Talk & system demonstration “Generating Data Analysis Programs from Statistical Models”, Workshop on Semantics, Applications and Implementation of Program Generation (SAIG), Montreal, Canada, 9/20/00.
32. Fischer, Bernd and Schumann, Johann. Talk & system demonstration “A System for the Synthesis of Data Analysis Programs”, NIPS*2000 Workshop on Software Support for Bayesian Analysis Systems, Breckenridge, CO, 12/1/00.
33. AutoBayes System Demonstrations for NASA researchers J. Scargle (Code SST), J. Coughlan (Code SGE), and to visiting scientist D. Basin (U Freiburg/Germany) and U. Martin (U St. Andrews/UK).
34. Schumann, Johann. Synthesis and Transformation of UML designs Design for Safety, NASA Ames, August 10, 2000.
35. Fischer, Bernd and Schumann, Johann. AutoBayes: System Demonstration, Kestrel Institute, Sept. 5, 2000.
36. Schumann, Johann. Amphion/NAV: Project Demonstration, Jan 31, 2001.
37. Schumann, Johann. AutoBayes: Talk and System Demonstration, Workshop Automated Deduction, Dagstuhl, Germany, Mar, 2001.
38. Schumann, Johann. Poster and System Demonstration on AutoBayes and Amphion/NAV, HDCC Workshop, Santa Cruz, May 7-8, 2001.
39. Schumann, Johann. Amphion/NAV: A System for the Deduction-Based Synthesis of State Estimation Software, RIACS Seminar, May 17, 2001.
40. Fischer, Bernd and Schumann, Johann. AutoBayes: Talk and System Demonstration, CALCULEMUS (during IJCAR’2001), 2001.

II.A.3.f Future Plans

One of the major future goals for this task will be to extend the domain coverage for the synthesis system. This means that more complex, and thus more NASA application-specific programs can be synthesized automatically. Furthermore, emphasis will be put on certification of synthesized code; an issue which is particularly important for code synthesis for safety-critical areas (e.g., state-estimation and navigation software). To this end, we will also work on extending our current techniques for documenting and explaining synthesized software (e.g., generation of standardized design-documents and hyper-linked code-documentation).

II.A.4 Advanced Autonomous Planning and Scheduling

II.A.4.a Task Summary and Overview

Planning and scheduling applications arise in many areas within NASA, including space exploration, Earth observation, rover operations, and air traffic management. While the applications are varied, the same basic problems are encountered in the different areas, the need for reasoning about interacting activities that share limited resources. Looking towards space operations as an example, we find that spacecraft, satellites and rovers have traditionally been operated by mission operators that build and test command sequences and then upload the result to be executed on board the spacecraft or rover in question. The drawbacks of this approach are the requirement for manpower to build and test sequences, the need for deep space communications to upload sequences at regular intervals, and the lack of flexibility during execution, enforced by the predetermined sequences. As more and more missions are active at the same time, each with limited resources and manpower, these drawbacks become significant obstacles. Furthermore, extended distant missions, such as exploring Europa, and missions with severely time-constrained decision-making windows, such as Mars rover explorations, cannot be effectively completed using traditional command sequencing methods.

Constraint-based planning is a promising paradigm for planning and scheduling operations in complex domains. The Remote Agent, which was flight validated on board the Deep Space One spacecraft in an experiment in May 1999, used an underlying constraint representation and reasoning mechanism. Furthermore, constraint-based planning has recently been identified as one of the most promising solution candidate for providing planning technology capable of handling issues such as time and resources. In constraint-based planning, activities and states are represented as temporal intervals that are connected by constraints. The result is a network of tasks that defines a set of plans. In addition to the increased expressiveness for reasoning about time and resources, the constraint-based reasoning approach allows arbitrary constraints to be represented, and supports almost any constraint-reasoning techniques for improving the efficiency of the reasoning.

The high-level goal of this task is to continue the development of cutting-edge constraint-based planning and scheduling techniques, to support NASA mission operations. This includes autonomous operations on board spacecraft and rovers, on ground autonomous plan generation and validation as part of mission operations, and mixed-initiative planning and scheduling tools to assist mission operators in decision-making and validation.

II.A.4.b RIACS Staff

Ari K. Jónsson

II.A.4.c Project Description

There are four main components to this project, which are intertwined through the common use of constraint-based planning technology:

- Constraint-based planning technology development: The goal is to develop advanced constraint-based reasoning techniques for effectively building and analyzing complex plans for system operations.

- Mixed-initiative planning tools for science operations: The general focus of this effort is to develop intelligent planning and scheduling tools that can assist operators with developing operations science plans for rover operations.
- Earth-observing satellite task scheduling: The goal is to develop techniques for automatically building observation task schedules for fleets of Earth-observing satellites.
- Prototype development of mixed-initiative science planning tool for Mars Exploration Rover (MER) mission: The goal of the effort is to develop and demonstrate a prototype interactive planning tool that would provide valuable assistance to the rover operators of the MER mission.

This project is done in collaboration with a number of other scientists and staff at Ames Research Center, including both civil servants (ARC) and contractors (RIACS and QSS), as well as with other scientists outside Ames. A part of this project is also related to another RIACS project. Following is an outline of the collaborations and relations:

- The constraint-based planning technology development, led by Ari Jónsson, is done in collaboration with Will Edgington (QSS), Jeremy Frank (ARC), and Paul Morris (ARC).
- The mixed-initiative planning technology development is done in collaboration with John Bresina (ARC) who leads the effort, Adans Ko (JPL), Pierre Maldague (JPL), and Karen Myers (SRI International).
- The Earth-observing satellite scheduling work is done in collaboration with Robert Morris (ARC), who leads the work, Jeremy Frank (ARC), and David Smith (ARC).
- The MER prototype planning tool effort is done in collaboration with Kanna Rajan (RIACS) who leads the effort, John Bresina (ARC), Will Edgington (QSS), Adans Ko (JPL), Pierre Maldague (JPL), and Paul Morris (ARC). The MER prototype planning tool development effort is also part of the Spacecraft Autonomy project, described in Section II.A.10.

II.A.4.d Accomplishments during FY2001

The key accomplishments this year were the increased use of the constraint-based planning system developed by this project, and the development of the mixed-initiative planning tool prototype for the Mars Exploration Rover missions. The prototype effort combined aspect of different components of this projects, including the mixed-initiative research work, the core constraint reasoning work, and the application of constraint-based planning to NASA mission problems. The highlight of the prototyping effort was a demonstration that was given to members of the MER team and other JPL personnel on September 28, 2001.

To outline the key achievements, we present them in three categories, combining the work on mixed-initiative planning and the work on the MER prototype:

II.A.4.d.i Constraint-based technology development

- The stability and efficiency of the constraint-based planning system were significantly improved, in particular in terms of testing, documentation, and reasoning efficiency, which are all crucial components of fielding the system in NASA applications.

- The number of projects building on the constraint-based planning system continued to grow. These projects include: *IDEA*, an execution agent architecture based on using planning to control execution, *SOFIA flight planning*, a research effort to develop a tool to assist in planning observations for the SOFIA airborne observatory, *Earth observation scheduling*, a research project to develop automated planning tools for fleets of satellites, *MER planner prototype*, an effort to demonstrate mixed-initiative planning for science operations scheduling, and more.
- Advances were made in the development of techniques for reasoning more effectively about resources, by developing methods that build resource usage envelopes for partial plans. The envelopes can be used to identify problems and help the planning system make good decisions about resource allocation.
- The notion of projected state spaces was developed further, to provide, among other results, a relation to mutual exclusion reasoning. The goal of this work is to provide a general method to guide planners in their search to find plans, without the need for extensive coding of domain-dependent heuristics.

II.A.4.d.ii Mixed-initiative science planning tool prototype for MER

- The constraint-based planning system was connected to APGEN, an existing mission operations planning tool from JPL. The APGEN system, which is being used in a number of different missions, offers a user interface to modify and examine plans. By connecting it to our planning system, APGEN users get access to constraint-based planning capabilities. The connection allows the users to invoke and use constraint reasoning, partial and full plan completion, decision retraction, and other useful functions. The results of any autonomous reasoning steps are immediately shown in the graphical user interface.
- The APGEN functionality that allows users to move activities in time was connected to the constraint reasoning framework to provide an intelligent move operation. The result is that the user is constrained to only moving an activity within a window of placements that do not violate the planning constraints, and any related activities are relocated as needed to account for the move.
- The planning search methods were extended to allow the rejection of unachievable goals, and to provide better control over the tradeoff between completeness and speed. A key component of the latter was a planning algorithm based on bounded backtracking.
- A planning domain model was developed to describe a set of MER rover systems, including the arm and the associated instruments, the mast and the associated cameras, the on-board CPU, the communications systems, and more.
- Different versions of the prototype were demonstrated to members of the MER team, including both operations and science staff, and other interested parties, culminating in a final demonstration on September 28, 2001.

II.A.4.d.iii Earth observation planning and scheduling

- An initial planning domain model for representing and planning for multiple Earth observing satellites was developed and demonstrated. This model supports arbitrary numbers of spacecraft with three types of remote sensors, as well as reasoning about

scheduling different observation requests to different satellites, taking into account the position, on-board sensor, etc.

- Planning guidance techniques, based on measuring and minimizing contention between different observations, were developed. Such techniques are crucial in domains such as Earth observing where there are large numbers of observations and observation opportunities.

II.A.4.e Publications and Presentations during FY2001

II.A.4.e.i Publications

58. Jeremy Frank, Ari K. Jónsson, and Paul H. Morris, “On Reformulating Planning as Dynamic Constraint Satisfaction”, in Proceedings of Symposium on Abstraction, Reformulation and Approximation (SARA), 2000.
59. Ari K. Jónsson, and Jeremy Frank, “A Framework for Dynamic Constraint Reasoning using Procedural Constraints”, in Proceedings of the Fourteenth European Conference on Artificial Intelligence (ECAI), 2000.
60. Jeremy Frank, Ari K. Jónsson, Robert Morris, and David E. Smith, “Planning and Scheduling for Fleets of Earth Observing Satellites”, in Proceedings of the Sixth International Symposium on Artificial Intelligence, Robotics and Automation in Space (iSAIRAS), 2001.
61. Jeremy Frank and Ari K. Jónsson, “Constraint-based Attribute and Interval Planning”, submitted to Journal of Constraints: Special Issue on Constraints and Planning, Eds: Alexander Nareyek and Subbarao Kambhampati.

II.A.4.e.ii Presentations

41. Ari K. Jónsson, Robert Morris, David E. Smith, “Autonomous Scheduling for Airport Operations”, presentation at RIACS Science Council Meeting, NASA Ames Research Center, November, 2001.
42. Ari K. Jónsson, “Planning and Scheduling for Fleets of Earth Observing Satellites”, presentation at the Sixth International Symposium on Artificial Intelligence, Robotics and Automation in Space (iSAIRAS), Montreal, Canada, June, 2001.
43. Ari K. Jónsson, Robert Morris, and David E. Smith, “First year project report: Planning and Scheduling of Earth Observations”, presentation and demonstration at Earth Sciences Technology Office, Goddard Space Flight Center, Maryland, July 2001. Dr. Jónsson’s role was to give a demonstration of the planning system.
44. Ari K. Jónsson and Kanna Rajan, “Mixed-Initiative Planning Prototype Demonstration for Mars Exploration Rover (MER)”, presentation and demonstration JPL, September 2001. Dr. Jónsson’s role was to give the interactive demonstration.

II.A.4.f Future Plans

The overall goal of this work is to continue the development of advanced constraint-based planning techniques, to continue advancing the state of the art, and to support NASA applications. The applications include mixed-initiative tools to assist rover and space-craft operators, as well

as autonomous systems for decision-making and verification, both on ground and in flight. Among more specific goals are the following:

- The development of better techniques for effectively reasoning about resource use in plans where activities and states have temporal extent
- The ongoing improvement of the core technology and the prototype system, to make it more effective and easier to deploy in its multiple uses
- The integration of constraint-based planning into APGEN, an existing NASA mission operations tools, to provide a mixed-initiative tools for mission operators
- The continued effort to develop a crucial mission operations tool, to assist in making good decisions about daily operations during the Mars Exploration Rover mission
- The development of techniques to combine centralized planning with on-board decision-making for maximizing the utility of fleets of Earth-observing satellites

II.A.5 Bayesian Inference and Image Analysis

II.A.5.a Task Summary and Overview

NASA's EOS program, as well as other data collecting government agencies (such as NOAA, USGS, NIMA, etc.) and industry generate vast sets of observational data of the earth. This data is a basic resource, that can help answer such basic scientific questions as global warming, changing land use, ocean circulation and so on. In addition this data provides the raw material for answering broad policy questions, such as crop assessment, forestry planning, urban planning, etc. Also, individual users may find this data helpful in providing information about their particular farm or community. Also, NASA has image processing needs for planetary rovers and for integrating information from multiple images of planetary surfaces. Given this range of users, this raises the question how can NASA best meet the information needs of these users?

Bayesian model-based data integration in principle solves the problem of how to integrate information from multiple sensors. However, there are many practical problems in constructing computationally efficient models, especially in view of the huge amounts of data involved. In the long run, it should be possible to integrate all satellite (or other) data into one global model as the data is received. This updated model can then be used to project particular information required by particular users. It is also very useful for spotting changes, because these are where there is a larger than expected difference between what the model expects and what is observed. The model can also be used to compress the data, since only the differences between expected and observed need to be stored. In the short term, this technology potential can be tested in much more limited demonstrations of data integration, such as integrating the images from the same satellite on different passes. This limited case is what the Bayesian Inference group is investigating.

This problem of integrating information from different sensors to answer particular questions is a familiar one in remote sensing and other fields, and often is referred to as "data fusion". "Data fusion", as sometimes envisioned, is a fundamental misconception. Data should ****never**** be tampered with, let alone "fused". Data is what was observed, and as such cannot be changed after the event. What basic theory says is possible is to construct geophysical models of the surface and

atmosphere that “best” predict the observed data. For example, a geophysical ground model would include a point-by-point description of the topography, ground cover types and spectral characteristics, soil types, moisture content, etc. From such a geophysical model, it is possible to project what a particular patch of ground would look like from a particular viewing angle, under particular lighting conditions, with a particular camera etc. That is, given the model, one can probabilistically predict what would be observed (the expected data). The difference between what is actually observed (the data) and the expected data can be used to update the model. Thus the model acts as the central repository of all the real information in the data and is constructed from our prior knowledge of geophysical processes and how radiation interacts with the geophysical system. This central model could loosely be described as the result of “fusing” the data, but it is not itself “data” or a “data product”. The Bayesian probabilistic estimation approach not only allows estimation of the most probable model given prior domain knowledge and the data, but it also estimates the uncertainty associated with the model. In particular, if this model uncertainty is high, it means that there is insufficient data/prior knowledge to pin down which model actually applies.

II.A.5.b RIACS Staff

Peter Cheeseman
Robin Morris
Frank Kuehnel
Udo Toussaint

Visiting staff:

Maurice Ringer (PhD student, Cambridge University, UK)

II.A.5.c Project Description

The basic theory behind our approach is that of inverse graphics. That is, if we knew what the ground is like, the lighting conditions, and the camera orientation and characteristics, etc., then we could predict what the camera would see (an image). This is the standard computer graphics problem. However, we have the inverse problem--we know what the images are, and we want to find the most probable ground truth (surface) that would have generated them, assuming we know the lighting conditions and camera characteristics. The most important (and difficult) part of this process is recovering the camera orientation and position for each image. To do this, we must register all the images with respect to each other to an accuracy of a small fraction of a pixel; this registration tells us how an image maps onto the ground truth model we are building.

Our initial ground model is formed by letting each pixel “vote” on what the corresponding ground position should be depending on how much that ground position contributed to that pixel. This initial ground model is then used to project what each image should be (i.e., predict each pixel value). The differences between the predicted pixel value and the observed value are used to update the ground model until it cannot be further improved. This procedure produces an increase in both spatial resolution and gray-scale resolution (super-resolution). We are now able to generate images from a high-resolution ground model, and then reconstruct the surface from these

images at a resolution much higher than the input images. We are currently trying to extend the system so that it can learn the camera parameters and lighting conditions while simultaneously inferring the unknown surface.

II.A.5.d Accomplishments during FY2001

We have been successful in reconstructing unknown surfaces from synthesized low-resolution images of that surface, even though the images are taken from different viewpoints and under different lighting conditions. The surface is reconstructed at much higher resolution than the input images (super-resolution). This is the first time this has been achieved to our knowledge. The results of this super-resolution can be seen on our web page: <http://www.arc.nasa.gov/~super-res/>

Our initial super-resolution surface reconstruction used artificial images generated from a digital elevation map, and LandSat images of the same area. We used artificial images because this allowed us to compare the true surface with our reconstruction. The reconstructed surface was within a fraction of one percent of the true value. However, since this initial success, we have been attempting surface reconstruction from real images. This required us to estimate both the camera parameters (internal and external) from the images, as well as reconstruct the surface. This requirement lead to considerable research on camera registration, which we recently achieved, and the surface reconstruction using the images and the inferred camera parameters, which we have also recently achieved.

II.A.5.e Problems Encountered and Possible Resolution

Instability of NASA Funding (from the 632 program). has caused much stress for FY00, FY01, and is likely to cause similar stress for FY02. Proposal writing to mainly NASA funding sources may generate sufficient funds to cover this research for FY02.

II.A.5.f Publications during FY2001

62. "A Bayesian Approach to High Resolution 3D Surface Reconstruction from Multiple Images", by R. Morris, P. Cheeseman, V. Smelyanskiy and D. Maluf.
63. "Bayesian Super-Resolved Surface Reconstruction from Images" V.N. Smelyanskiy, P. Cheeseman, D.A. Maluf and R.D. Morris, *Computer Vision and Pattern Recognition*, June 2000.
64. "Matching Images to Models -- Camera Calibration for 3D Surface Reconstruction" R.D. Morris, V.N. Smelyanskiy, P. Cheeseman, *Energy Minimization Methods in Computer Vision and Pattern Recognition*, Springer Lecture Notes in Computer Science volume LNCS 2134, Sept. 2001.

II.A.5.g Future Plans

For FY02, the Bayesian computer vision research is focused on using information from real images, using real cameras to build 3-D surface models. This requires the simultaneous estimation of the camera parameters (extrinsic) and the estimation of the surface shape and reflectance

properties. We intend to be able to recover the surface shape and reflectances at super resolution for selected areas, as the full super-resolution algorithm is too expensive to be applied globally.

II.A.6 Spatial Statistics and Forecasting

II.A.6.a Task Summary and Overview

This task involves research in Spatial Statistics and Forecasting for Earth Science Data. The research describes a number of motivating problems that identify areas where the interaction between computer science/statistics and the Earth Science community can identify non-trivial statistical problems that are of great interest to the domain experts. The work in addressing these problems, and the interactions generated, will naturally identify further areas of research.

II.A.6.b RIACS Staff

Robin Morris

Visiting Staff

Dr Dmitri Luchinskii (Lancaster University, UK)

II.A.6.c Project Description

The Earth Science community spends a great deal of effort and resources making measurements of the biosphere. Often, however, it is either

- impossible to measure directly the quantity of interest,
- while it is possible to make the measurements, no current sensor exists, or
- it is only feasible to make very sparse, point measurements of a quantity that is spatially continuously variable.

In all cases, statistical analysis of the data that is available can produce estimates of the quantities of interest, and make significant contributions to our ability to understand and forecast the biosphere.

The work in this task will begin to address these problems. Working from specific examples identified by members of the Earth Science community, general approaches to broad classes of statistical problems in Earth Science will be developed.

As an example, ecologists are interested in quantifying soils, and in quantifying the Available Water Capacity (AWC) of soils over large regions. However, measurements of soils are typically made by a scientist in the field digging up samples of the soil, and analyzing the samples in his or her laboratory. Clearly it is only feasible to sample soils at a small number of discrete locations. The soil scientist will then, using their expertise, determine which areas on a map are likely to

have similar soils to their samples, and divide the map into regions, allocating a single soil measurement to each.

Another biospheric parameter of interest is Leaf Area Index (LAI). While it is not possible to measure LAI directly, it can be easily and reliably estimated from satellite remote sensing data. The ecological theory of “hydrologic equilibrium” gives a relationship between LAI and AWC, but this relationship is statistical rather than deterministic. The question then naturally arises: how best to use the LAI data and the hydrologic equilibrium information to estimate AWC on the same support as the LAI data, and how best to estimate the uncertainty of the AWC values reported. This is a type of disaggregation problem, where covariate information is present.

The work in this task is directed at precisely formulating the statistical problem implied in the description above, analyzing the mathematical structures, and implementing algorithms to perform the disaggregation. A problem in a similar vein is disaggregating the output of a coarse-grained climate model, using fine-grained vegetation measurements as the covariate information.

Biospheric prediction and forecasting are of great interest. Ecologists spend much time and effort developing models for biospheric processes. These models are usually deterministic, giving a prediction of the future given values for the current and short prehistory of the inputs. However, when these models are used to predict more than a short time into the future, they can give unreliable estimates, with no estimate of the uncertainty associated with the prediction.

Fires are one of the major events influencing the development of forests, and as such are of great ecological and economic importance. The prediction of forest fires is therefore a problem of great interest to Earth Scientists and Foresters. Earth Scientists know a great deal on the qualitative level about the factors that influence the susceptibility of a forest area to fire, but detailed prediction of the fire risk is still beyond the state of the art. A forest fire can be considered as an extreme event, or “large deviation” in the normal behavior of the forest. The statistical theory of large deviations says that there is a prehistory to the rare event that manifests itself in the dynamics of the system. Bayesian inference tells us how to infer the characteristics of the dynamical system from the data recorded for the forest area. This allows us to learn the correlations between the biospheric parameters which are predictive of the increased fire risk. By identifying the trajectories of the dynamical system model which result in large deviations, it should be possible to give more accurate prediction of the fire risk.

The problems described are characteristic of the types of spatial statistical problems that arise in Earth Science data and biospheric modelling and prediction. The interaction between the statistics/computer science researchers and the Earth Science domain experts that will arise out of this task will naturally identify further classes of statistical problem, which will motivate generally applicable statistical solutions.

II.A.6.d Accomplishments during FY2001

The statistical theory for the AWC/LAI disaggregation problem was completed, and together with Monika Mellem, a visiting student under the NASA USRP program, an initial implementation was developed to validate the theory.

Under the fire prediction subtask, together with Dr Luchinsky, an initial study was made of the climate database prepared by Dr Neemani (UMT), to search for rare events (determined to be regions with extremely high fire frequency), and to then study the prehistory of these events to determine the correlation structure leading up to these events. This initial study has revealed some interesting structure in the data, and has identified the need for better data resolution.

II.A.6.e Problems Encountered and Possible Resolution

The work to date has identified the need to obtain more detailed climate and fire start data to support this work. We are actively working with the Earth Scientists involved in this project to obtain this data. We are also working to use the biogeochemical simulation systems (eg BEHAVE) to simulate forest evolution and fire starts.

II.A.6.f Presentations during FY2001

45. Robin D Morris, "Spatial Statistics and Forecasting for Earth Science", NASA IS/IDU Workshop, Missoula Montana, June, 2001.

II.A.7 Robust Task Execution for Robotic Exploration of Planetary Surfaces

II.A.7.a Task Summary and Overview

Future planetary exploration missions require new methods of commanding and controlling robotic agents on distant planetary, comet, and asteroid surfaces. Communication with robotic agents operating on distant planetary surfaces is severely constrained by bandwidth limitations, opportunity windows, and round-trip communication time delays. The limited ability to communicate with remote robotic agents requires onboard software that is capable of reliably selecting and executing sequences of actions to accomplish task plans uploaded by Earth-based operators.

The main objective of this task is to develop reinforcement learning methods for learning optimal conditional action selection policies which are capable of reliably accomplishing robotic tasks. The approach is to learn a conditional action plan for each robotic task. Examples of robotic tasks are: "egress from lander", "acquire waypoint position", "acquire soil sample", "acquire rock core sample", "acquire images", "deploy spectrometer on rock", etc. A conditional action selection policy consists of a set of conditional action rules which deterministically map each robot state to the optimal action to execute in that state.

The benefits of using deterministic optimal action selection policies onboard remote planetary robots are: significant increases in the science data yield and number of tasks performed per uplink/downlink command cycle; reduces ground support personnel requirements; improved robustness to common robot faults and failures; minimizes the onboard computer power, memory and software complexity; simplifies software verification for flight; and enables future robotic

exploration missions which require multiple days of autonomy, and low mass, low power robotic vehicles.

II.A.7.b RIACS Staff

John Loch

II.A.7.c Project Description

The main product of this task is the development of an automated method of determining optimal conditional action selection policies to accomplish rover tasks such as “waypoint acquisition”, “acquire rock sample”, and “deploy spectrometer on rock”. A conditional action selection policy consists of a set of conditional action rules which deterministically map each robot state to the optimal action to execute in that state. Machine learning techniques, mainly reinforcement learning and neural networks, will be utilized to learn the optimal conditional action selection policy.

Learning of the conditional action selection policies will occur in two stages, first using a simulation of a rover in Mars-like terrain, and secondly using the K9 Mars rover hardware prototype in the NASA Ames Marscape outdoor test environment. The use of the simulated rover will allow for faster learning of simple conditional action rules, such as backing up when the rover has collided with a rock or turning in the right direction to avoid terrain hazards. The conditional action rules are then refined using real-world experience from the K9 rover operating in the NASA Ames Marscape outdoor test environment.

The resulting conditional action selection policy learned from this two stage process is a deterministic mapping from the rover perceived state to the optimal action to execute in that state in order to accomplish the high-level task objective. Once learned, the conditional action selection policy can be implemented as a simple lookup table and requires little onboard rover computation to implement. Verification of the correct operation of the conditional action selection policy is simplified since the plan is deterministic.

II.A.7.d Accomplishments during FY2001

- Completion of faster than real-time rover-terrain simulator. Rover-terrain simulator uses simple rover model incorporating probabilistic wheel slip on flat terrain with cylindrical obstacles. Rover-terrain simulator is coded in C++ using object-oriented methodology.
- Developed baseline sensor suite and discretization method for the rover waypoint acquisition task.
- Learned action selection policies for 3 different sensor discretization levels showing performance improvements with finer sensor discretization levels.
- Verified the optimality of the learned action selection policy for the coarse sensor discretization level.
- Developed a new method for incorporating memory into the learned action selection policy which greatly improves task performance.

II.A.7.e Problems Encountered and Possible Resolution

The main problem encountered during FY2001 was due to time commitments I had to other projects in FY2001. This limited the amount of time I could devote to this task to a 50% level for FY2001. In addition, the supporting team members on this task, Hans Thomas, Justin Boyan, and Vineet Gupta, are no longer at NASA Ames and therefore did not provide the expected support. Despite these limitations, much progress was made on this task during FY2001.

II.A.7.f Publications during FY2001

65. Loch, John, "Using Active Memory to Get MDP Performance on POMDP Problems", (to be submitted) Nineteenth International Conference on Machine Learning, July 2002.

II.A.7.g Future Plans

Research plans for FY 2002 are to complete work for publication of research results for the ICML 2002 conference paper. The active memory method developed and tested using the POMDP problems used for the paper will be applied to the rover waypoint acquisition problem. Results with and without active memory will be generated using both simulation and the K9 rover in the NASA Ames Marscape outdoor test environment.

II.A.8 Model-Based Autonomy (MBA)

II.A.8.a Task Summary and Overview

The Model-Based Autonomy task is currently made up of two separate areas of work — integrated vehicle health maintenance, and diagnosis for planetary rovers. Dr. Bajwa is involved with the IVHM effort, while Dr. Dearden is the P.I. for the planetary rover work.

The NITEX (NASA IVHM Technology Experiment) aimed to demonstrate the use of model-based diagnosis for integrated vehicle health management (IVHM). The project had collaborative participation from three NASA Centers: Ames Research Center (ARC), Glenn Research Center (GRC) and Kennedy Space Center (KSC).

The product of NITEX is an integrated software package containing monitor algorithms and a diagnostic program, Livingstone, to track and diagnose the operation of a Main Propulsion System (MPS) of a Reusable Launch Vehicle (RLV) prototype such as the X-34. Release 1 of the software demonstrated diagnosis of the liquid oxygen (LOX) sub-system of the MPS during the captive carry phase of flight. This was achieved through use of a qualitative model of the components of the system in order to determine when an off-nominal condition occurs and in order to pinpoint the failed component. As of now, all NITEX work is documented on Postdoc and is accessible to project members only.

The work on diagnosis for planetary rovers is aimed at providing on-board diagnosis, situation estimation, and resource estimation capabilities. It is funded by both the Intelligent Systems

programme, and by the Mars Exploration programme, and it is hoped that the rover on the Mars '07 mission will use the software we develop.

In contrast with the symbolic approach to diagnosis used in Livingstone, the rover diagnosis work is based on *hybrid diagnosis*, in which the continuous nature of a system (in this case, a rover) is explicitly reasoned about to perform the diagnosis. Although this approach makes the diagnosis algorithm more complex, we believe that its greater representational power is necessary to successfully diagnose systems such as the rover in which there is a very complex interaction between the system and an unknown or only partially known environment. In addition, this approach should allow us to estimate future resource usage based on the diagnosis of the rover's internal state and its environment.

II.A.8.b RIACS Staff

Anupa Bajwa
Richard Dearden

Visiting Staff

Jonathan Moody
T. K. Satish Kumar
Todd K. Leen

II.A.8.c Project Description

II.A.8.c.i Integrated Vehicle Health Maintenance

The main architectural blocks of the NITEX software are a Real-time Unit (RxU) and a Ground-Processing Unit (GPU). The RxU, which runs on a VxWorks simulator, provides real-time processing of telemetry data for tracking vehicle component status and detecting off-nominal conditions. The GPU provides visualization, explanation and archiving of vehicle data and experiment status results. The main components of the RxU are:

- Monitors, which listen in on the (simulated) telemetry stream for command and sensor data in order to detect changes in the system's state
- Real-Time Interface (RTI), which translates this information into a qualitative, discrete format and which decides when to issue a diagnosis request
- Livingstone, which is the inference engine
- Results Output System (ROS), which stores the diagnostic output and the
- Telemetry Input System (TIS), which provides status and event information for display to the ground operator using the GPU.

II.A.8.c.ii Diagnosis for Planetary Rovers

Diagnosis of hybrid systems is essentially *Bayesian belief updating*. One starts with some prior beliefs about the state of some system, and a model of how that system evolves over time, and then conditions the prior belief distribution on the observed behavior of the system to produce a

posterior belief distribution, or diagnosis. A diagnosis, in this context, is for every state, the probability that the system is in that state, given our prior beliefs about the system and the sensor values we have observed, and can be computed using Bayes rule. Unfortunately, computing this posterior distribution exactly for a hybrid system is computationally intractable, especially on-board a rover.

Our diagnosis work has concentrated on techniques for doing approximate Bayesian belief updating efficiently, and in particular on *particle filters*. A particle filter approximates a complex distribution by a set of weighted samples or particles from that distribution. To perform belief updating, a predictive model is used to estimate a possible future state for each particle, and then the weight of the particle is multiplied by the likelihood of observing the sensor values if the predicted future state was the true state of the system. The set of re-weighted samples constitutes an estimate of the belief distribution given the observations. The approach is faster and simpler than full belief update, but may require a large number of samples. Our work on this project has largely been in the area of finding ways to reduce the number of samples needed to accurately approximate the true belief distribution, particularly given the characteristics of diagnosis problems, in which low-probability events such as faults occurring are very important to diagnose correctly.

II.A.8.d Accomplishments during FY2001

The NITEX demonstration included fourteen scenarios (one nominal operation and thirteen failure scenarios) that were diagnosed in the LOX sub-system during the captive carry phase of flight. The software successfully tracked the state of the system through the nominal operation and it correctly diagnosed the simulated faults for each failure scenario. Dr. Bajwa's main contribution to the project is in the domain knowledge acquisition and modeling effort, and in exercising the system to make it robust and accurate.

Summer Intern (SSRP01) Jonathan Moody of CMU worked on extending the Hybrid Concurrent Constraints (HCC) language to include probabilities. HCC is a separate modeling language and currently is not being used for the IVHM task. However, since HCC is useful for describing quantitative models of a system, it is possible that it can be integrated for IVHM use in the future. HCC is also being considered for building simulations for the rover diagnosis work, and as a predictive model of a system that can be used in hybrid diagnosis.

Summer Intern T. K. Satish Kumar did theoretical work unifying ideas from discrete and hybrid diagnosis techniques, including Bayesian inference, and constraint satisfaction problems. He showed that these problems, as well as a number of others, can be translated into model-counting problems. Since approximate model counting algorithms can be polynomial in certain cases, this work may allow the development of faster algorithms for both these problems.

Dr. Dearden is currently developing algorithms for approximate hybrid diagnosis that are efficient enough that they could be used on-board a rover. A simple particle filter algorithm has been developed and applied to actual data from the Marsokhod rover. Some naïve approaches to reducing the number of particles needed have been implemented and tested, with promising results.

Professor Todd K. Leen (Dept. Computer Science and Engineering, OGI School of Science & Engineering, Oregon Health & Science University) participated in a related project on Local Adaptive Algorithms for Sensor and Data Understanding. See Section II.A.9 below for details.

II.A.8.e Problems Encountered and Possible Resolution

The X-34 RLV Program was cancelled during the course of this project. NITEX however, achieved its goal using simulated data and simulated scenarios to demonstrate the diagnostic software. The X-34 MPS can be modeled as a generic propulsion system hence the NITEX diagnostic software can be modified to model any liquid propulsion system.

II.A.8.f Publications and Presentations during FY2001

II.A.8.f.i Publications

66. Dearden, Richard. "Structured Prioritized Sweeping." Proceedings of the Eighteenth International Conference on Machine Learning, 2001.
67. Dearden, Richard and Clancy, Dan. "Particle Filters for Real-Time Fault Detection in Planetary Rovers." To appear at the European Space Agency Workshop on On-board Autonomy, October 2001.
68. Bajwa, Anupa. Software Test Report (STR) For the X-34 NITEX Experiment -- Release 1 Thread Demonstration. (Project deliverable document, co-authored with William Maul from NASA GRC)

II.A.8.f.ii Presentations

46. Bajwa, Anupa. "Livingstone Overview" and "X-34 IVHM Technology Experiment" presented in Poster Presentations and Software Demonstrations at *Inspection 2000*, Houston, TX, November 2000. (Supported the Outreach Group in Code IC in the creation of the posters)
47. Verma, Vand; Simmons, Reid; Clancy, Dan; and Dearden, Richard. "An Algorithm for Non-Parametric Fault Identification." Extended abstract presented at *AAAI Spring Symposium on Robust Autonomy*, Stanford University, March 2001.
48. Dearden, Richard. "Probabilistic Fault Detection of Hybrid Discrete/Continuous Systems." Presented at the NASA Intelligent Systems workshop, Pasadena, August 2001.
49. Dearden, Richard. "Real-time Fault Detection and Situation Awareness for Rovers." Presented at the NASA *Mars Technology Program Rover Technology workshop*, Pasadena, September 2001.

II.A.8.g Future Plans

PITEX (Propulsion IVHM Technology Experiment) is a collaborative project, with Northrop Grumman Corporation (NGC), in the IVHM Technology Area, under NASA's Space Launch Initiative (SLI) Program. In FY02 the model-based IVHM work will continue to be refined and extended in order to demonstrate the scalability of the system (for instance, extend the diagnostic model by adding components and sub-systems such as RP-1), and in order to demonstrate the

ability to handle sensor noise and sensor failures. When a suitable vehicle platform is available, this technology will be demonstrated as a flight experiment.

The work on rover diagnosis will be ongoing over the next two years, with the eventual goal of integrating the diagnosis system with the rover platform to be used on Mars in the Mars '07 mission. As well as the work on diagnosis algorithms, predictive models of the rover dynamics must be developed, possibly using the HCC modeling language mentioned above, and the models and diagnosis algorithm must be integrated into the CLARAty architecture being developed at Ames and JPL for use on the rover.

II.A.9 Local Adaptive Algorithms for Sensor and Data Understanding

II.A.9.a Task Summary and Overview

The original proposal described objectives for a three-month visit at NASA Ames Research Center to establish ties with appropriate research and directed technology projects, begin application of modeling to the those projects, and identify areas where expanded fundamental development and algorithm synthesis will provide solutions to NASA problems.

II.A.9.b RIACS Staff

None

Visiting Staff

Todd K. Leen (OGI)

II.A.9.c Project Description

During summer of 2000, Professor Leen visited at NASA ARC to identify project areas that would benefit from his work in adaptive statistical modeling. Discussions with numerous groups included Dan Clancy and his group, Irv Statler and his Batelle PNL and ARC collaborators, Peter Cheeseman and his group, Ed Huff and his group, and Chuck Jorgensen and his group. A strong mutual interest and collaborative fit surfaced with Ed Huff's group, working on adaptive techniques for fault detection in rotating machinery. Leen began preliminary work with the group that included literature search of models for gear vibration production and exploratory analysis of NASA data to identify signal features indicative of faults.

II.A.9.d Accomplishments during FY2001

Early success in feature identification, and the need for integrating machine learning techniques into the group's fault detection work provided impetus for drafting a proposal for the NASA Intelligent Systems/ Intelligent Data Understanding research initiative, and a summary proposal to the Design for Safety initiative. Our proposal for collaborative work with Dr. Huff's group was funded.

II.A.9.e Presentations during FY2001

50. Leen, Todd, K. "Machine Learning in Rotocraft Health Maintenance", *NASA IS/IDU Workshop*, Missoula Montana, June, 2001.

II.A.9.f Future Plans

A graduate research assistant is involved in the project research, and has visited ARC. Leen and his colleagues will continue in close collaboration with ARC through visits funded in part by the IS award, and in part by funds from RIACS. Our ongoing work will include statistical modeling of rotorcraft vibration signals with the aim of building on-board fault-detection systems based on a combination of fundamental physical models and real-time adaptive statistical models.

II.A.10 Spacecraft Autonomy

II.A.10.a Task Summary and Overview

Autonomous systems are increasingly not just relevant, but critical for NASA in its goal for an aggressive exploration program of deep space. Autonomy is not just a requisite tool for achieving lower operational costs, but in many cases is an enabler of missions. For example, a highly autonomous rover with smart resource management software could not only systematically explore and traverse large tracts of the Martian surface, but could also conserve power to handle serendipitous scientific activity. A potential underwater mission to the oceans of Europa will not be conceivable without substantial onboard autonomy. Autonomy is also highly desirable when menial tasks can be offloaded to a software assistant executing on a micro-robot, that faithfully executes the tasks for an astronaut onboard the International Space Station, thereby saving valuable human time, energy and effort. This not only saves costs but also results in a highly productive and habitable workplace in space's hostile environment. Such capabilities in agent software are currently outside the scope of what can be done in realistic environments. Extensive theoretical work in building and merging temporal plans, dealing with uncertainty and building dispatchable plans that can be executed in real time, requires pushing the envelope in the areas of constraint based Planning, Scheduling and Execution. The objective of this task therefore is to provide the tools and techniques to enable such fundamentally different missions for NASA and to provide a sustainable software infrastructure so that developmental costs can be minimized. As a first step, NASA Ames (and one of the RIACS staff attached to this task; Rajan) demonstrated for the first time, closed-loop autonomous control of a NASA spacecraft by flying the Remote Agent onboard Deep Space One. Further research is now being undertaken as part of this task to push the envelope to provide such systems where the craft is in closer contact with the environment (such as Rovers) and also to close the loop on the ground using human-in-the-loop Mixed-Initiative Planning Systems.

The spacecraft autonomy project includes research on autonomous operation of rovers. The subject areas involved in this research are agent architectures, robust and flexible plan execution mechanisms, execution-time resource management, on-board state identification and fault diagnosis, and plan revision to adapt to changing situations. The rover domain presents new and different requirements from spacecraft in that the agent's behavior cannot be separated from the complex environment in which it operates. The work has involved a close collaboration with other

researchers in the Autonomy and Robotics Area of NASA Ames, in particular in the areas of planning and scheduling, robotics, and visualization. In addition, the work has involved collaborations, primarily with the University of Massachusetts on fundamental research and with JPL on rover testing. The goal of the rover autonomy work is to demonstrate, within NASA and the larger scientific community, the vital role that advanced agent architectures and execution technologies play in intelligent control of complex systems such as rovers.

II.A.10.b RIACS Staff

Kanna Rajan
Richard Washington

Visiting Staff

Dan Bernstein, University of Massachusetts (short-term visit)
Alton Crenshaw, Florida A&M (summer student 2001)

II.A.10.c Project Description

- Doing core research and development in autonomy towards fielding software in realistic mission scenarios. This effort includes communicating results through conferences, workshop and journal publications and presentations.
- Connect with external entities to enable ARA technology pipeline especially to NASA missions.
- Build a group dealing with the critical issue of command and control for Distributed Spacecraft.
- Build connections with academia and industry to further the strategic vision of ARA.
- Undertake group lead duties for Spacecraft Autonomy for ARA and help provide guidance in the developing the long terms strategic needs of the area.
- Interact with peers outside ARC to keep current in the state-of-the-art and to be proactive in seeking opportunities for research and deployment for ARA technologies.

The research objectives of the rover autonomy subproject fall into two areas:

- Rover autonomy. This work centers around the command executive prototype for the K9 rover, which forms a basis for ongoing research projects as well as serving as the function command executive for rover operations. The research projects have concentrated on robust, flexible execution of plans, using a utility-based approach. More recent work has explored on-board plan adaptation and plan merging techniques, which lie somewhere between execution and full-scale planning. The rover autonomy project also collaborates with Richard Dearden (RIACS) on state identification and fault diagnosis techniques for rovers.
- Verification and validation (V&V) for rovers. This work is in collaboration with D. Giannakopoulou (RIACS) and K. Havelund (QSS) of the NASA Ames V&V group to explore testing of V&V techniques on the rover executive. The eventual goal is to improve the design of the execution architecture while validating V&V techniques on large, operational systems.

II.A.10.d Accomplishments during FY2001

- Applied research efforts in search control and planning/scheduling for Mars 03 MER (see below) and Distributed Control as mentioned above.
- Leading a combined Ames and JPL team to provide the Mars03 MER mission with a software prototype for building sequences rapidly during mission ops. This is an intensive development effort requiring all of Rajan's time in Spring and Summer 2001 to enable the mission to review a software demo in the September timeframe. This has involved extensive on-site discussions at JPL and attending meetings with MER personnel (about 200hours spent). The work is still in progress with periodic reports to Dave Lavery (Hq), Jim Erickson (JPL/MER) and Steve Zornetzer (ARC) due every month. This is a high visibility, high-risk endeavor and has consumed all of Rajan's time. At the time of writing this report there is a very high possibility that our team will indeed become part of the MER baseline Ground Data System.
- (Planning) Community activity:
 - Workshop Co-Chair, organizer of the student scholarship program and Program Committee member AIPS2002, Toulouse, France.
 - Program Committee, European Space Agency workshop on Onboard Autonomy, Noordwijk Holland, October 2001
 - Workshop co-chair, NASA Earth Science Enterprise Workshop on Distributed Control, Alexandria, VA, January 2001.
 - RIACS, Associate Director
 - Technology reviewer for New Millennium Program, 2001.
 - Technology reviewer for ASI Scientific programs, Italian Space Program 2001.
 - Program Committee North American Chair for AI, iSAIRAS 2001, Montreal, Canada.
 - Chair, NASA Planning/Scheduling workshop Executive Committee.
 - Chair, ARA Hiring Committee, NASA Ames Research Center.

II.A.10.e Publications and Presentations during FY2001

A number of presentations were made external to ARC. I'd have to look it up in more detail.

II.A.10.e.i Publications

69. Washington, Richard, Golden, Keith, and Bresina, John. "Plan Execution, Monitoring, and Adaptation for Planetary Rovers," *Electronic Transactions on AI* (Electronic journal, web site www.etaij.org), Vol. 4, Section A, pp. 3-21, December, 2000 (revised version March, 2001).
70. Cardon, S., Mouaddib, A.-I., Zilberstein, S., and Washington, R. 2001. "Adaptive Control of Acyclic Progressive Processing Task Structures," *Proceedings of IJCAI-2001*, Bernhard Nebel, ed., Morgan Kaufmann, 2001. (co-author)

71. Bresina, John L., Bualat, Maria, Fair, Michael, Washington Richard, and Wright, Anne, "The K9 On-Board Rover Architecture," *Proceedings of the ESA Workshop on On-Board Autonomy*, Eric Bornshlegel, ed., 2001. (co-author)
72. Bresina, John L., Bualat, Maria, Edwards, Laurence, Washington, Richard, and Wright, Anne, "K9 Operations in May '00 Dual-Rover Field Experiment," *Proceedings of the 6th International Symposium on Artificial Intelligence, Robotics, and Automation in Space (i-SAIRAS 2001)*, 2001. (co-author, presented paper at conference)
73. Edwards, Laurence, Flueckiger, Lorenzo, and Washington, Richard, "VIPER: Virtual Intelligent Planetary Exploration Rover," *Proceedings of i-SAIRAS 2001*, 2001. (co-author, presented paper at conference)
74. Bernstein, Daniel S., Zilberstein, Shlomo, Washington, Richard, and Bresina, John L., "Planetary Rover Control as a Markov Decision Process," *Proceedings of i-SAIRAS 2001*, 2001. (co-author)
75. Bresina, John L. and Washington, Richard, "Robustness via Run-time Adaptation of Contingent Plans," *Proceedings of the AAAI-2001 Spring Symposium: Robust Autonomy*, 2001. (co-author, presented paper at conference)

II.A.10.e.ii Presentations

51. Washington, Richard, "Markov Based Localization Device for a Mobile Robot," *i-SAIRAS 2001*, Montréal, Canada, June, 2001. (presented for absent colleagues)

II.A.10.f Future Plans

- Lead a successful team to change the way sequencing is done for complex missions such as Mars03.
- Continue to be involved in the planning and scheduling community by attending workshops and conferences and provide support in organizing them.
- Continue to provide leadership within the Autonomy and Robotics Area at ARC.
- Build bridges with JPL and other NASA centers to build a technology pipeline for ARC products.

The near-term research emphasis in rover autonomy will be on more fully characterizing capabilities that we have designed for on-board plan adaptation, followed by integration and testing of these techniques. In collaboration with university researchers, we will develop Markov-model techniques for choosing rover targets and activities. In addition, more sophisticated resource management techniques will be integrated into the on-board control architecture, allowing the rover to make decisions based on current and predicted resource availability. A future direction is to investigate techniques for efficiently exploring unknown planetary environments, which would combine planning, terrain traversability calculations, computer vision techniques, and 3D modeling.

II.A.11 Visual Odometry and Target Tracking

II.A.11.a Task Summary and Overview

This task is less than half year old and in its preliminary evolution. The task involves accurate estimation of position and orientation of a rover during long traverse. Various algorithms such as Structure from Motion (SFM) and stereo motion analysis were studied. Sensitivity of SFM – linear and non-linear techniques – has been a concern, while their performance, compared to short baseline stereo has proven better for our tasks.

II.A.11.b RIACS Staff

Esfandiar Bandari

Visiting Staff

Ecleamus Ricks (Morehouse College)

Mathew Deans (CMU).

II.A.11.c Project Description

Our objective is to find position and orientation of (the expandable) rover over time, as it traverses the Martian terrain. The term Visual does not exclude use of the IMU or onboard odometry hardware such as gyros, but is intended to complement these devices, increase their accuracy, and overcome some of their systematic errors such as drift.

Several sources of visual information can be tapped into, for instance incremental horizon or analyzing direction of shadows to determine the relative rover orientation. But our goal is to find robust, fast and accurate methods that build on proven method.

II.A.11.c.i Stereo For Odometry

As part of our work we looked into both stereo and SFM for estimation of rover motion. Needless to say that SFM, if implemented accurately and efficiently holds a greater amount of promise, but the ideal system should merge the results of both stereo displacement estimation for fast accurate short motion estimation and SFM for long-range position and orientation estimation. In short stereo motion can be characterized as:

- Good for short range 3D reconstruction {depth of reconstruction is 25 ± 5 times the stereo baseline. This is the general rule of thumb from photogrametry. Of course it depends on the camera resolution and field of view (plus the amount of overlap)}.
- Fast {stereo, motion pipeline}, accurate, and fairly robust. Accuracy does drop with depth
- Can use alignment of incremental 3D stereo recons {by matching 3D features, correlating surfaces, tracking 2D and 3D features, verifying motions and distances, etc. etc.} for building accumulated model and incremental estimation of motion.

Critical elements:

- will fail if the rover gets into featureless regions or where 3D or 2D structures are distant
- model matching has to be done over short motion ranges
- it has to be done very fast {getting all 6 degrees of motion}
- it has to avoid any systematic errors
- it has to be sensitive to errors in orientation

II.A.11.c.ii Panspheric Camera

Determination of orientation can be important over time, particularly for the odometry using stereo. Horizon detection and DEM have been used for determination of rotation and position, but it requires very stable (horizontal) platform {to fractions of degrees}, with the horizon detection begin semi-automatic in an atmosphere-less environment (e.g. moon) or completely clear skies. We have looked at panspheric cameras for fast acquisition of surround data. Simply matching distant features (not necessarily on the edge of sky) is more robust, available, and relevant in the context of SFM.

II.A.11.c.iii Structure from Motion (SFM)

- Long range navigation requires camera localization over large disparities and time spans.
- Stereo (or trinocular) reconstruction while accurate one reconstruction at a time, requires 3D/2D integration, and special requirements such as small size and orientation footstep over reconstruction and presence of features over individual footsteps.
- Stereo, while a powerful approach which we will be studying later {hopefully with Issa}, it also means that we require complementary methods for failure avoidance and verification.
- Rover motion provides long baseline which makes it ideal for structure from motion {in fact given camera positions over long range motion, one can think of standard stereo as a special case of 3D from long baseline motion.}.
- The scale ambiguity in SFM -- critical for odometry -- can be easily addressed with stereo {OK so what does this mean. When a camera moves around, we want to extract the motion of the camera and the structure of the scene. It is easy to see that one can reduce the size of the objects in the scene and proportionately reduce the motion of the camera and get the exact same images. This means that there is basically a multiplication number (a single number only) that specifies the scale of motion and structure and that can not be recovered in SFM.}
- SFM requires:
 - feature extraction
 - registration and matching (addressed via motion pipeline).
 - outlier rejection
 - camera calibration (auto-calibration or prior calibration)
 - structure and motion determination

We have addressed the majority of these topics including feature extraction, calibration and registration in our work so far.

- Majority of the methods are two frame SFM at a time (factorization method by Triggs can handle multiple frames in projective space but they are transformation ambiguous and have not been studied for effects of outliers and errors in matching).

II.A.11.d Accomplishments during FY2001

A list of our accomplishments in the above projects included writing feature extraction, tracking, camera calibration and porting them to a small rover for testing, plus various sensitivity analysis for SFM. Also we:

- set up ATRV Jr. stereo rig,
- put together a Linux based stereo calibration tool (extrinsic parameters and all intrinsic parameters including radial distortions)
- wrote a motion pipeline program (can be used for fast stereo pipeline)
- wrote another proposal with Issa Nesnas of JPL that fits this project best and provides additional resources.

II.A.11.e Problems Encountered and Possible Resolution

- Lack of resources and expertise have been our primary concern, especially given the scope of the task.
- Funding from JPL seems to get cut. I am looking into further funding from DARPA.

II.A.11.f Publications and Presentations during FY2001

II.A.11.f.i Publications

76. Wolpert D., Bandari E., and Tumer K., "Improving Simulated Annealing by Recasting it as Non-Cooperative Game", NASA/TM-2001-210929, Sept 2001
77. Wolpert D., Bandari E., and Tumer K., "Improving Simulated Annealing by Replacing its Variables with Game-Theoretic Utility Maximizers", NASA/TM-2001-21030, Sept 2001
78. Deans, M. "Maximally Informative Statistics for Localization and Mapping", IEEE Conf. Robotics and Automation, 2001.

II.A.11.f.ii Presentations

52. Ricks, E. "Camera Calibration and Feature Tracking", Minority Research and Education Programs (MREP), NASA Ames, August 2001

II.A.11.g Future Plans

Acquiring more funding from DARPA and continuing with the new project with JPL on merging of 2D and 3D feature points.

II.B Human-Centered Computing

Many NASA missions require synergy between humans and computers, with sophisticated computational aids amplifying human cognitive and perceptual abilities. Areas of collaboration between RIACS and NASA scientists are described in the following sections.

II.B.1 Work Practice Analysis

II.B.1.a Task Summary and Overview

The focus of the Work Practice Analysis research is on understanding how people and systems are interconnected in practice. To accomplish this, research is conducting in the areas of work systems analysis and evaluation and the development of computational modeling tools for simulating how people collaborate, communicate, and work within their environment.

The research conducted under this task is an integral part of the Work Systems Analysis and Evaluation group in Code IC. The group's research philosophy is based on the view that Human-Centered Computing is a software engineering methodology. This methodology is based on the scientific study of cognition in people and machines, especially understanding the differences between perceptual-motor/cognitive/social aspects of people and present-day computer systems with the objective of developing computer systems that fit human capabilities and practices by exploiting and improving AI programming methods.

II.B.1.b RIACS Staff

Maarten Sierhuis

Visiting Staff

Alessandro Acquisti (Visiting Ph.D. Student, UCB)

Charis Kaskiris (Visiting Ph.D. Student, UCB)

Zara Mirmalek (Visiting Student, California State University Hayward)

II.B.1.c Project Description

The following projects were conducted and/or participated in under this task during FY01:

II.B.1.c.i Human-Robotic Teamwork in Practice

In this project we are studying the work practices of astronauts onboard the International Space Station (ISS), using available data in the form of ISS documentation and training manuals, field trips to Johnson Space Center (JSC), and most of all ISS video data provided to us by the video library at JSC. The funding of this project comes from the NASA Cross-Enterprises and the IS programs. We are collaborating with the Institute for Human and Machine Cognition of the University of West Florida (IHMC), to develop an *agent architecture for autonomous space systems* of the future that perform many tasks involving close to real-time cooperation with people

and with other autonomous systems. While these heterogeneous cooperating entities may operate at different levels of sophistication and with dynamically varying degrees of autonomy, they will each require some common means of representing and appropriately participating in joint tasks. Models of human-robotic “teamwork” that will support the use of autonomous systems in operational environments must be grounded in studies of actual work practice and not merely abstract theory.

In this effort, we combine the talents of members of our research team at RIACS and IHMC to develop theory and tools necessary for supporting “design to implementation” approaches for the Personal Satellite Assistant robot developed at NASA ARC that can be generalized straightforwardly to other space systems.

II.B.1.c.ii Mobile Agents

This project will develop a *distributed human-robotic EVA system for surface exploration*. Basic advances in information systems architecture are required to integrate the robotic systems, life support system, pressure garment, communications network and display (inside the helmet), navigation and sample collection tools, and analysis instruments. This project will develop a seamless intelligent system that integrates data from the system’s agents (robots, suit, tools, etc.), provides this data on the surface to the rover and to remote mission support (with time delay), and uses software “intelligent agents” to interpret this data to provide model-based advice pertinent to carrying out efficient and safe EVAs. The agents will nominally run onboard mobile computer systems, hence they are called “mobile agents.” Agents will be implemented in the multiagent simulation system (Brahms), which will be refined and adapted to serve as a real-time system. In addition, a state-of-the-art spoken dialogue interface will be integrated with Brahms models, to support a speech-driven field observation record and rover command system (e.g., “return here later and bring this back to the habitat”). This combination of agents, rover, and model-based spoken dialogue interface constitutes *a rover assistant*.

II.B.1.c.iii Brahms/CONFIG

An integrated simulation model which merges two existing simulation tools, Brahms (RIACS & NASA/Ames) and CONFIG (NASA/JSC). The combined simulation will integrate models of environmental systems and crew activities with autonomous agent software controlling life support systems. The integrated systems-human behavior simulation will be useful for debugging control software, planning and scheduling resources and crew activities, and providing a means for the crew itself to visualize alternatives for day-to-day scheduling (such as for planning a significant change in their daily routines). By modeling the layout of the chambers explicitly and including models of human activity (their life, not just control actions), perspectives of multiple disciplines (e.g., architects, life support engineers, crew planners) can be integrated, such that layout designs and crew work schedules can be properly planned and understood. On this basis, interactions between systems-maintenance and scientific work can be discovered and appropriately accounted for in automated systems, procedures, training, and external support.

II.B.1.c.iv RIACS/Digitalspace STTR

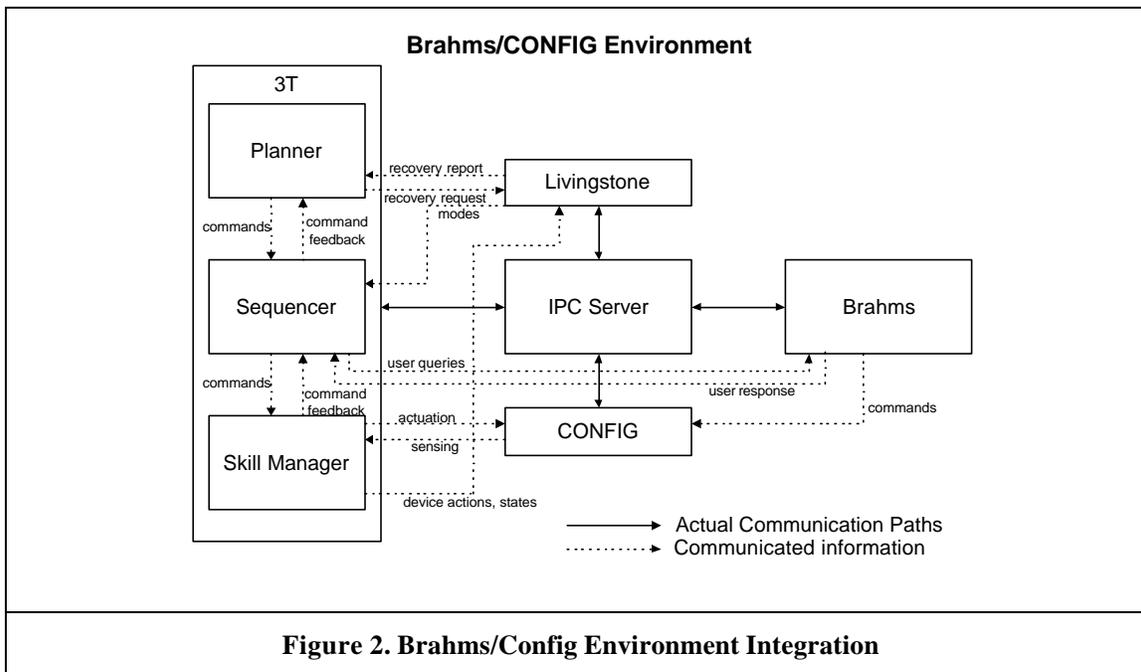
We were research partners in a Phase I STTR with Digitalspace, Inc. In this first phase we helped in the definition and development of a *3-dimensional virtual reality interface* between our Brahms tool and the OWorld Virtual World of Digitalspace (BrahmsVE). With this BrahmsVE we are able to generate 3-dimensional models and simulations of a work system. The purpose of such an end-user interface is multi-dimensional, and includes, but is not limited to, the development of just-in-time training systems and virtual worlds for collaboration over distance.

II.B.1.c.v A Human-Centered Computing Study of Delays at United Airlines

This project is a NASA-sponsored research task investigating delay activities within an airline organization. This was a third study in a series that is part of a NASA initiative to improve the efficiency of the air traffic system. This year’s study set out to demonstrate how departure delays, which appear to occur at the gate, actually result from events that occur earlier in the process of moving customers from the curb to the plane. The findings are the result of a work practice study conducted over a four-month period at the United Airlines Domestic Terminal in the San Francisco International Airport. In this qualitative research study we have used the method of participant-observation to collect data from the different communities of employees and customers involved in the curb-to-plane portion of air travel.

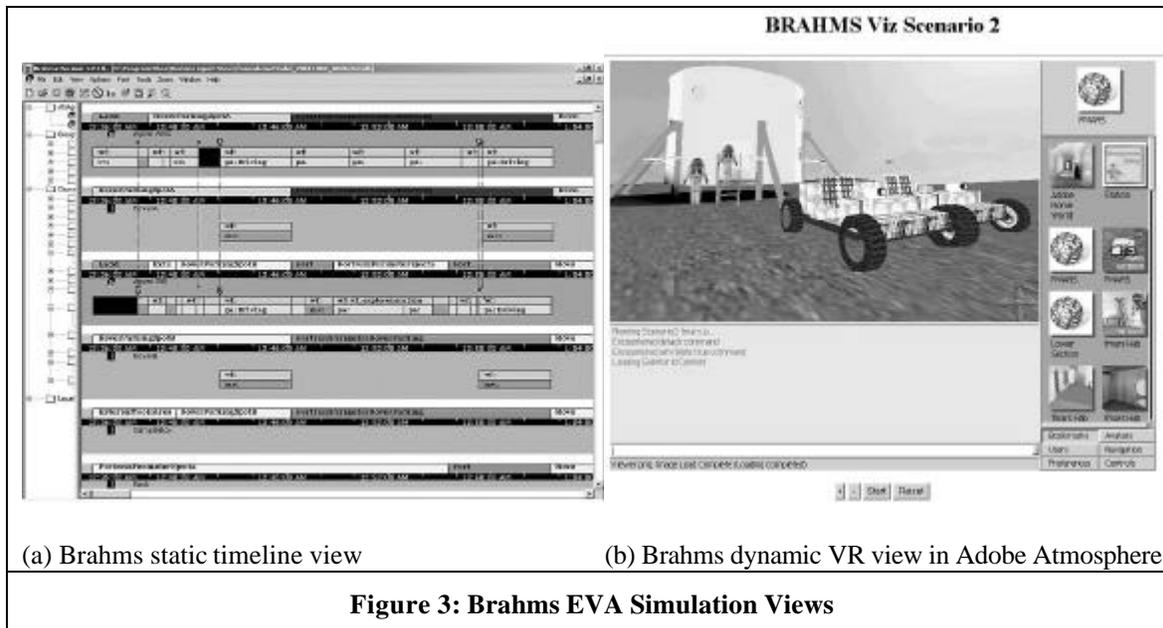
II.B.1.d Accomplishments during FY2001 during FY01

Brahms/Config simulation systems integration. This system proves the use of Brahms in an integrated simulation environment (see [79]). The research showed how Brahms could be integrated with other software environments, using the Brahms Java application interface.



Brahms Dynamic Virtual Reality Environment. As a result of the Phase-I STTR with Digitalspace, Inc., we developed a prototype demonstration of a virtual reality interface for

Brahms. As is shown in the two figures bellow, the result of a Brahms simulation of two astronauts performing an EVA on their rovers, outside the FMARS habitat on Devon Island (**Error! Reference source not found..a**), can be “played-back” over the web in the Adobe Atmosphere Virtual World rendering engine (**Error! Reference source not found..b**).



Finished Doctoral Dissertation In September 2001, Maarten Sierhuis successfully defended his doctoral dissertation on “Modeling and Simulating Work Practice,” at the University of Amsterdam [80]. The dissertation is the result of three-years of Brahms research performed as part of funded USRA/RIACS and NASA research projects.

Brahms Tutorial. Under research direction and supervision, visiting student Alessandro Acquisti developed an extensive Brahms tutorial. This tutorial is freely available to internal and external Brahms users, and is meant as a comprehensive guide to the Brahms modeling language and simulation environment [86].

UAL Work Practice Study Report: Visiting student Zara Mirmalek performed two extensive ethnographic observation studies for United Airlines (UAL) on location at San Francisco airport. She reported on these two research tasks in two separate research reports, see publications [87] and [88].

II.B.1.e Publications and Funded Proposals during FY2001

II.B.1.e.i Publications

79. M. Sierhuis, “Modeling and Simulation for Work System Design,” Computational & Mathematical Organization Theory, vol. 7, 2001.
80. M. Sierhuis, “Modeling and Simulating Work Practice; Brahms: A multiagent modeling and Simulation language for work system analysis and design,” Doctoral dissertation in

- Social Science and Informatics: University of Amsterdam, 2001, The Netherlands: pp. 350.
81. A. Selvin, S. B. Shum, M. Sierhuis, J. Conklin, B. Zimmermann, C. Palus, W. Drath, D. Horth, J. Domingue, E. Motta, and G. Li, "Compendium: Making Meetings into Knowledge Events," presented at Knowledge Technologies 2001, Austin, TX, 2001.
 82. J. Conklin, A. Selvin, S. Buckingham-Shum, and M. Sierhuis, "Facilitated Hypertext for Collective Sensemaking: 15 Years on from gIBIS," presented at Hypertext 2001, University of Aarhus, Århus, Denmark, 2001.
 83. W. J. Clancey, P. Lee, and M. Sierhuis, "Empirical Requirements Analysis for Mars Surface Operations Using the Flashline Mars Arctic Research Station," presented at FLAIRS-2001 Conference, Key West, FL., 2001.
 84. W. J. Clancey, D.M. Torok, M. Sierhuis, R. J. J. v. Hoof, and P. Sachs, "Simulating Work Behavior," in United States Patent Office. USA: Intitute for Research on Learning and Bell Atlantic Network Services, Inc., 2001.
 85. J. M. Bradshaw, M. Sierhuis, Y. Gawdiak, R. Jeffers, N. Suri, and M. Greaves, "Adjustable Autonomy and Teamwork for the Personal Satellite Assistant," presented at IJCAI '01, Seattle, WA, 2001.
 86. A. Acquisti, M. Sierhuis, "Brahms Tutorial", Brahms TM01-0002, RIACS, NASA Ames Research Center, 2001.
 87. Z. Mirmalek, "Inside a Minute-and-a-Half: Customer and Employee Perspectives in Work System Design", RIACS, NASA Ames Research Center, 2001.
 88. Z. Mirmalek, "Waiting at the Gates: Participant-observation among Employees & Customers in the Gate Process", RIACS, NASA Ames Research Center, 2001.

II.B.1.e.ii Funded FY'01 Research Projects

- "Multi-Agent Software Design and Engineering for Human-Centered Collaborative Autonomous Space Systems". Funding awarded by NRA 99-OS-05 - Cross Enterprise Technology Development Program.
- "Teamwork in Practice: Design for Collaboration in Mixed Human-Robotic Teams". Funding awarded by NRA 2-37143 - Intelligent Systems Program.
- "Work Practice Simulation Environment for Habitat Design and Scheduling". Funding awarded by NRA 2-37143 - Intelligent Systems Program)
- "Mobile Agent Architecture". Funding awarded by NRA 2-37143 - Intelligent Systems Program.
- "Brahms VE: A Collaborative Virtual Environment for Mission Operations, Planning and Scheduling", Phase I. Funding awarded by STTR program.

II.B.1.f Future Plans

In FY'02 we will be working on four Brahms modeling efforts:

- a model about "a day in the life on board the ISS" This model will show the work of the crew members on board the ISS, based on a video analysis of ISS videos returned from the station.
- a model about human-robot collaboration of a Mars EVA. This model will be a detailed plan and schedule for a field experiment in the new Mars habitat in the Utah dessert.

- a model of Mission Operations and the Athena robot for the MER'03 mission. In this project I am supporting the development of a Brahms model by the Ames HCC MER project.
- a model about "a day in the life of the FMARS habitat on Devon Island". In this project I am supporting Bill Clancey in the development of a Brahms model.

Furthermore, in the event that our Phase II STTR with Digitalspace is funded, we will continue with the development of our Brahms Virtual World interface. This will lead to a real-time VR interface with the Brahms simulation engine.

Digitalspace will be funded to help with the development of two Virtual Worlds. One will be the VW of the FMARS habitat on Devon Island. The second one will be a VW of inside the ISS. Both will be in support of our two modeling efforts as mentioned above.

The Brahms team will also continue the development of a Brahms Interactive Development Environment, as well as continued improvements to the Brahms language and virtual machine.

II.B.2 Spoken Language Interfaces to Complex Systems

II.B.2.a Task Summary and Overview

The goal of the RIALIST (Research In Advanced Language, Interfaces and Speech Technology) group is to conduct leading edge research on advanced dialogue capabilities for multimedia dialogue systems and apply these results to applications in NASA programs. Our focus is on Spoken Dialogue Natural Language Interfaces to semi-autonomous agents and training systems. There are many different types of agents being developed by NASA giving a rich variety of possibilities for experimentation. The research builds on extending and augmenting established speech and language technology such as the Nuance recognizer and the SRI Gemini and Open Agent Architecture systems.

The current research focuses on contextual interpretation, portability, asynchronous dialogue management, and natural dialogue designs. Present implementation efforts include a spoken dialogue interface to the Brahms multi-agent modeling system and to the Europa planner. Future research topics include prosody focus for system spoken output, dialogue move based dialogue management, language modeling based on sparse training data, rational integration of multiple knowledge sources, and evaluation of confirmation methods for collaborative dialogues. A new demonstration prototype based on the planner interface to the next generation Personal Satellite Assistant simulator is being developed.

Our group is actively exploring ways to integrate spoken dialogue interfaces into current and future NASA missions. Areas of interest include spoken dialogue interaction with robotic agents including planetary rovers and assistant robots for the International Space Station like the PSA and AERCam, dialogue based training, augmentation of air traffic control, multi-media dialogue interfaces including eye tracking, and intelligent cockpit instrumentation.

NASA has a major issue on longer missions including the International Space Station and manned Mars exploration of providing ground assistance to the astronauts and rovers. The old models of 24/7 staff availability from Mission Control are being stretched beyond human capability by these long missions. Clearly a way to provide assistance from the ground which involves fewer people is to use computer systems with spoken dialogue interfaces to provide information and expert advice. These systems need to be so easy and natural to use that special training will not be required. The systems need to have the dialogue behavior of humans built into them. Our approach is based on empirical studies of what people say to each other, what people say to actual systems and what they say to simulations of possible future systems.

Speech recognition and natural language processing have been developed over the past ten years so that commercial dialogue systems are used providing airline information, stock quotes and directory assistance. However, NASA's needs in this area differ from the commercial sector in at least two ways:

- NASA requires interfaces for many quite diverse applications. The number and diversity of NASA applications drives the need for research in portability, that is the ability to use and /or adapt language resources and system components to multiple applications
- Many NASA applications, such as collaborative rovers will require dialogue capabilities that are likely to be beyond the state of the art for commercial systems for the foreseeable future. NASA systems need to be robust and accurate, accept any well formed sentence and operate over special domains.

Part of our approach to addressing NASA's needs in the area of spoken language dialogue interfaces is to leveraging off state of the art commercial and research software and extend these systems in the areas of portability and advanced capabilities. Our relationships with many of the leading edge groups allow us to use otherwise secret features of the commercial systems to NASA's advantage. The commercial companies have hundreds of programmers who work on making their speech recognition and synthesis faster, more robust and capable of recognizing and generating natural speech. Fast and robust recognition and natural sounding speech synthesis are extremely important attributes for spoken dialogue systems, if they are to be useful as the primary interfaces to complex systems.

II.B.2.b RIACS Staff

Jim Hieronymus
John Dowding
Beth Ann Hockey
Frankie James (until March 2001)

Visiting Staff

Jason Baldrige
Ellen Campana, SSRP Student
Matt Ginzton
Stanley Peters, Visiting Scientist

II.B.2.c Project Description

Future NASA missions require improved methods of human-computer interaction based on spoken natural language dialogues. Astronauts building the International Space Station or on planetary surfaces will need to be able to carry out many tasks without using their hands to interact with computers and robotic systems. Spoken dialogue systems are the natural way to provide this much needed interface to external devices.

NASA has also been tasked with helping to improve air traffic control and cockpit efficiency. The air traffic controllers need to maintain visual contact with and attend to planes and tracking instruments, and should not be distracted by the demands of providing data to the air traffic control system. Since all of the relevant information is spoken already, a spoken dialogue system which performs helpful listening could provide the necessary data. Increasingly complex aircraft cockpits can provide much needed information to pilots, especially in emergency situations. However the user interfaces often require hundreds of keystrokes to obtain this data. An advanced dialogue interface can provide a natural way to ask for the information, and receive it in a timely fashion.

Innovative spoken dialogue interfaces are one area in which research developments can contribute to increased efficiency, robustness and safety of these missions. An important part of creating performance enhancing systems is to have interfaces that do not in themselves create additional work or cognitive burden. Imagine how much easier it would be to use a computer system that you could simply converse with in the same way you would when delegating to a human assistant or as you would when collaborating with a colleague. Especially good payoffs for using spoken interfaces are:

- Augmenting tasks already using voice -- capturing information from conversations between pilots and air traffic or ramp controllers
- Allowing collaboration with semi-autonomous agents that are engaged in activities that are normally accomplished using language -- astronauts in space suits interacting with groups of semi-autonomous rovers and astronauts.
- Allowing computer interaction in challenging environments or when hands are impeded by space suits or pressurization -- data entry, command and control.
- Completing complex, high workload tasks -- controlling complex computer systems where it is possible that one voice command can accomplish the equivalent of many keystrokes or mouse moves and clicks.

At the heart of the work is the question of understanding and modeling how people communicate, of exploring what representations can facilitate that communication either with other humans or with computer and robotic systems. Our approach is based on empirical study of what people say to each other, what people say to actual systems and what they say to simulations of possible future systems. We believe that one of the benefits of a spoken dialogue interface is that the closer it is to handling the types of conversations that people would have with each other, the more the interface provides a reduction in required training and in cognitive load.

II.B.2.d Accomplishments during FY2001

II.B.2.d.i Dialogue Interface to the Europa Planner

Developed a spoken dialogue interface to the Europa planner for the PSA project. The dialogue allows new goals and constraints to be added to the plan, and the planner will re-plan and report whether the re-planning was successful. Additional capability to ask the PSA where it is located at present has been developed. Collaboration with Greg Dorais, Yuri Gawdiak, and Nicola Muscettola.

II.B.2.d.ii Dialogue Interface to Brahms

Built a spoken dialogue interface to the Brahms work practices and knowledge capture modeling system which allows belief addition and revision. These are the first steps to a more capable spoken interface to this system. Collaboration with William Clancey and Maarten Sierhuis.

II.B.2.d.iii Eye Tracking

Built a multi-modal dialogue interface to the PSA-Space Shuttle simulator which allows the user to gaze at the microphone in order to talk to the system. This was integrated with the multi-modal interface capability of this system. Ellen Campana was the SSRP student who worked on this project and whose proposal won continuing funding for this work.

II.B.2.d.iv Open Source NLP

Developed a public domain front end processing system which allows the transformation of various natural language formalisms between each other. This allows a Gemini grammar to be used in the Stanford LinGO HPSG grammar parser. This was demonstrated at Stanford. The system will allow the same grammar (to within constraints imposed by differences in the grammar structure) to be used in a number of different parser.

II.B.2.d.v Collaborations

Developed collaborations with:

- The Stanford Semantics Lab headed by Stanley Peters with Oliver Lemon and Ann Bracey.
- EU Siridus project (Gothenburg U.(Sweden), University of Seville (Spain), Telefonica (Spain), and SRI Cambridge (UK))
- Ted Burger (USC)
- Lee Stone and Roger Remington (Code IH, NASA Ames)
- Walter Johnson (Code IH, NASA Ames)
- Nancy Smith (Code IH, NASA Ames)
- Liz Shriberg and Andreas Stolcke (ICSI and SRI)
- Alex Rudnicky (CMU)

II.B.2.d.vi Proposals

Submitted 1 NSF Proposal, 1 IS proposal and 1 HEDS proposal.

II.B.2.d.vii Recruiting

Recruited two new PhD. Researchers and hired one of them (Gregory Aist, to start November 2001).

II.B.2.e Problems Encountered and Possible Resolution

We have solved our office space problem by moving to T27A (behind Building 158), which has given us space for offices and for a lab. After the usual turbulence of moving and finally getting our computers to work on a NAS subnet, we have greatly enjoyed the new environment.

II.B.2.f Publications and Presentations during FY2001**II.B.2.f.i Publications**

89. Dowding, John, Hockey, Beth Ann, Gawron, J. Mark, Culy, Chris "Practical Issues in Compiling Typed Unification Grammars for Speech Recognition," ACL 39th Annual Meeting, Toulouse, France, July 2001.
90. Rayner, Manny, Dowding, John and Hockey, Beth Ann, "A Baseline Method for Compiling Typed Unification Grammars into Context Free Language Models", Eurospeech 2001 Scandinavia, Aalborg, Denmark, September 2001.
91. Samuelsson, Christer and Hieronymus, James, "Using Boosting and POS Graph Tagging to Improve Speech Recognition", Eurospeech 2001 Scandinavia, Aalborg, Denmark, September 2001.
92. James, Frankie, Rayner, Manny, Hockey, Beth Ann, and Bhagat, Amrita, "Comparing Accuracy and Coverage: Usability in Spoken Language Interfaces," Int. Conf. on Intell. User Interfaces, Sante Fe, NM, January 2001.

II.B.2.f.ii Presentations

53. Hockey, Beth Ann, "Grammar Compilation Rocks (If your grammar is just right)" SIGDIAL Workshop Panel on "Spoken Dialogue Systems: Theory that is Ready for Practice":
54. Hieronymus, James, "Spoken Dialogue Systems for Robot Control and Aircraft Cockpit Advisors," Talk to the Air Force Research Lab, Crew System Interface Division, July 2001.

II.B.2.g Future Plans

Goal: Creating natural spoken dialogue interfaces to robots, aircraft, spacecraft, air traffic control and instructional systems which are flexible to use and model human behavior.

II.B.2.g.i Advanced Dialogue Management

Continue to work on systems capable of task and dialogue initiative. Build task domain knowledge into the system, so that the system can make detailed suggestions and inquire about the task being done. Closely modeling human behavior will make the system seem natural for users and let it respond in ways which users expect. We are using information states to allow the user to respond to a question by giving the answer, asking a clarification question, answer another relevant question or abandon the present task and start over. We will continue to explore the problem of asynchronous dialogue management to include back channel processing which confirms that the listener has heard the point the system just made, back channeling by the system to assure the listener that the system is listening, and barge in, when the user takes over the turn when he has received enough information to respond.

II.B.2.g.ii Advanced Dialogue Language Modeling

Language models need to be robust and flexible for recognizing sensible but slightly ungrammatical speech. The rules of spoken English are more relaxed than grammar rules for writing. We are exploring ways in which the spoken grammars are less restrictive than written ones, so that the resulting grammars are more robust to real speech. Generation language models need to be able to construct interesting explanations for instructional dialogues. Generally the explanations will be constructed from logical forms which represent what the items to be explained actually are. We would like to be able to determine the user's level of expertise and construct the instructions and explanations at the appropriate level. We are examining technical support dialogues in order to determine some of the strategies for doing this successfully.

II.B.2.g.iii Prosody and Phrasing in Dialogue Systems

The prosody (i.e., intonation, loudness and duration) of words in a dialogue signal major phrase boundaries, focus words and the distinction between questions and statements. The focus words usually carry the most important meaning in the sentence and should be carefully analyzed by the speech understanding component. We are researching ways of putting prosodic features onto word lattices to help in parsing, and finding the meaning of the utterance spoken to the system. We are working with labeling and analyzing a database of dialogues with the PSA simulator system to find out how users prosodically marked their interaction with the system.

Prosody is important for the system's speech synthesis, to make the intended meaning clear. If the system asks "Where do YOU want to GO?", this is confusing because it seems to be asking which one of you wants to go where. The correct intonation is "WHERE do you want to go?"

II.B.2.g.iv Advanced Multimedia Dialogues

Dialogue accuracy and usefulness can be enhanced by using other modalities besides speech. Eye gaze and touch screens are two examples of input modalities which are useful in dialogues. These gestures will be treated as dialogue moves with a particular purpose in the overall utterance. Eye gaze for example can be used to disambiguate pronoun references, if the person is looking at the scene being described. Studies have shown that people who are describing a scene, look at the object they will be speaking about approximately 250 msec before they say the word. It is also

possible that eye movement will signal when the wrong action is being taken by a dialogue system. We will collect data and determine if this eye movement is reliable and useful for signaling speech understanding errors.

II.B.2.h Other Information

Our website is: <http://www.riacs.edu/research/detail/rialist>

II.B.3 NASA Astrobiology Institute Collaboration Technology

II.B.3.a Task Summary and Overview

The NASA Astrobiology Institute (NAI) was established in 1998 to encourage and fund collaborative multidisciplinary research in astrobiology and to foster innovative contributions to the scientific research agendas of NASA space missions. NAI represents a partnership between NASA and a number of academic institutions and research organizations and is currently composed of 15 Lead Research Teams which together represent over 700 investigators located at over one hundred institutions across the United States. The NAI administrative group, known as NAI Central, is situated at Ames Research Center.

Since an overarching shared goal of the NAI and its members is innovative research in astrobiology with an emphasis on collaborative work, both within and among its geographically distributed teams, NAI was conceived from the beginning to operate as a “virtual institute”. To meet its virtual institute objectives NAI planned for the deployment of various communication/collaboration tools (hardware and software), the development of community building efforts including opportunities for scientific interaction potentially leading to new collaborations within and among NAI Teams, and on-going evaluation of collaboration support in order to continuously develop and improve the effectiveness of NAI.

RIACS supports the continued development of NAI through providing staffing for the role of NAI Collaborative Research Manager. The primary responsibility of this role is to provide leadership in defining, evolving, implementing, and maintaining an integrated collaborative infrastructure, including the appropriate technology architecture that will support the goals of the NAI as a virtual institute.

For more information about the NASA Astrobiology Institute, please visit <http://www.nai.arc.nasa.gov>.

II.B.3.b RIACS Staff

Lisa Faithorn

II.B.3.c Project Description

Lisa Faithorn is the Manager of Collaborative Research for NAI. A primary responsibility of this role includes guiding research and implementation efforts of state-of-the-art and -practice tools and infrastructure that result in a “center without walls” in which scientists can perform their research without regard to geographical location - interacting with colleagues, sharing data and computational resources, accessing instrumentation, retrieving information from digital libraries and contributing to a shared knowledge base as the field of astrobiology develops. Responsibility also includes overseeing the successful operations of the technology infrastructure components already in place.

An additional component of this RIACS task is participation in this research arena by attending and presenting at conferences, as well as publishing the results of NAI experimentation in the virtual scientific institute concept.

II.B.3.d Accomplishments during FY2001

- **Redefinition of the Collaborative Research Manager Role to Fully Integrate a Technology and Human User Perspective and Development of the Collaborative Research Support Team**

The development of virtual collaborative spaces for scientists, such as NAI, is emerging as an important arena for both theoretical and applied research that draws on technological and social scientific knowledge and expertise. As a cultural anthropologist with experience working within contemporary organizational settings and building and facilitating collaborative teams, both face to face and virtual, L. Faithorn has brought a social science perspective to issues of technology architecture design which has impacted the definition and scope of the Collaborative Research Manager role. As a result, she has enlarged the focus from the technology itself to the larger social context of the realities of the NAI membership, a group of individuals of diverse disciplines, institutions, experience, professional motivation, scientific need and technology interest and competence.

L. Faithorn also created the Collaborative Research Support Group including members of the NAI Operations Team from Code JT and relevant staff from NAI Central. The team meets every other week to problem solve operational issues, strategize future directions and develop a shared knowledge base of NAI “lessons learned” from on-going efforts to further the virtual institute concept.

- **Ethnographic Site Visits to Lead Teams**

As part of a research process designed to gain fuller understanding of the purpose, composition and activities of the diverse NAI Lead Teams, L. Faithorn traveled around the country to all of the eleven original lead institution sites, as well as two of the four new sites that were added this past summer. During these site visits she conducted ethnographic interviews with the Principal Investigators of each team, as well as with a number of their Co-Is, technology support staff and administrative staff. A report including a discussion of key issues emerging from this research is currently in preparation. One important finding from this initial research with the teams is that NAI can do more to provide intra-team

collaboration support. Historically the focus has been more on building NAI's technology infrastructure for collaboration across teams, particularly among the PIs of each team.

- NAI Member-wide Communication/Collaboration Needs Assessment

During the summer of 2001, L. Faithorn designed a Communication/Collaboration Needs Assessment that was made available electronically to all members of NAI in early September. The survey was designed to collect data on a range of topics associated with extending the communication and scientific collaboration options available to NAI members. This included information about the geographical distribution of each team, the kinds of collaborative activities members would like to engage in, identification of key collaborators from the point of view of the survey respondent, and specifics about the particular IT equipment available to each member given their locations. The data is now ready to be analyzed and compiled into a report that can be used to guide further planning and implementation of collaborative research support.

- Comparative Study of Commercially Available Collaboration Tools

L. Faithorn worked with Claude Whitmyer and Gail Terry Grymes of FutureU in San Francisco to design a comparative study of collaboration tools that represent options commercially available to NAI. The assessment looked at a range of features associated with these tools to determine what capabilities were being offered by leading edge industry developers. When complete, this study will be a useful source of possible solutions to communication and collaboration requirements identified by NAI members through the Needs Assessment. Demonstrations of the most promising of these tools has begun and will continue this next year. L. Faithorn arranged for a demo by WebEx to the Ames Collaboration on Collaboration group earlier in 2001. WebEx is one of the commercial service providers whose solutions are included in the comparative study.

- Successful Resolution of Problems with NAI Videoconferencing among the Lead Institutional Sites

The original NAI IT Implementation Plan called for the deployment of videoconferencing equipment to all eleven of the initial NAI Lead Institutions particularly to facilitate communication among the PIs who together constitute the NAI Executive Council. The plan was to hold monthly videoconferences with the Council to conduct NAI business. A multicontrol unit(MCU) was installed at Ames to support these and other NAI related multiple site videoconferences. These meetings were routinely disrupted by technical problems with equipment or lines resulting in extreme frustration on the part of all participants. L. Faithorn worked with the NAI Operations Team from CodeJT, and most particularly with Steve Kyramarios, the Operations Team Lead to ensure complete diagnosis of these on-going problems. The result was the return for full cost of the MCU, after incompatibility issues with other system components were discovered. A new MCU of a different model was acquired that was compatible with the rest of the system and with significantly improved videoconferencing capabilities, at the equivalent cost of the faulty

MCU. Successful multipoint videoconferences are now being held among the Lead Institutional Sites and satisfaction levels have greatly improved.

- Initiation of Desktop Videoconferencing and Data Sharing Pilots

The NAI membership is widely distributed beyond the Lead Institutional Sites. Even at the Lead Sites, researchers are in different departments and often in buildings at some distance from another. Thus the Polycom videoconferencing system is not accessible to many key stakeholders within the NAI community. This has led to an experience of non-inclusion in the NAI virtual institute on the part of some members, and to only minimal NAI support of collaboration needs within teams.

L. Faithorn worked with the NAI Operations Team from Code JT to research and implement several different desktop videoconferencing pilots to explore feasible options for NAI members. Pilots are currently being undertaken with the staff of NAI Central at Ames, as well as with small groups of collaborators drawn from some of the NAI teams. These pilots are resulting in useful “lessons learned” and important information relevant to the deployment of desktop solutions on a community-wide level in the future.

- Initiation of Scientific Collaboration Projects

L. Faithorn initiated several projects to support scientific collaboration of various kinds among NAI distributed teams. One project centers on ScienceOrganizer, a specialized web-based project information repository to facilitate collaboration among members of distributed science teams. ScienceOrganizer is designed by Rich Keller and his team from Code IC. L. Faithorn worked with Rich Keller to expand the pilot project that was underway with members of the ARC NAI Team and to initiate new pilots with members of the JSC NAI Team and the NAI Ecogenomics Focus Group, a cross-team scientific collaboration.

Another project utilizing Concept Mapping, a tool developed by a group from Ames and the University of South Florida, was initiated by L. Faithorn, working with Geoffrey Briggs, Center for Mars Exploration. This pilot is intended to offer support to the work of the NAI Mars Focus Group, another of NAI’s cross-team scientific collaborations.

L. Faithorn also worked with M. Johnson and R. desJardin of NREN to develop potential collaborative projects with NAI scientists working in remote field sites while collaborating with colleagues elsewhere. The initial pilot utilizing NREN’s high speed network connectivity capabilities was unable to be implemented because of changes in the NAI researcher’s time table. Other pilots are being explored.

II.B.3.e Problems Encountered and Possible Resolution

Incompatibility issues between PC and Mac desktop videoconferencing/data sharing software. Possible solutions are either Web-based systems or new developments in cross-platform collaboration tools.

II.B.3.f Presentations during FY2001

55. Faithorn, Lisa, “NAI Review of Remote Collaboration Efforts” Presentation to Center Deputy Director Bill Barry in preparation for a briefing to the Administrator, Dan Goldin, Ames Research Center, October 25, 2000
56. Faithorn, Lisa, “NAI Collaborative Research Support”, Presentation to the Astrobiology Task Force, Ames Research Center, October 30, 2000
57. Faithorn, Lisa, “NAI Collaboration Support Goals and Projects” Presentation to NAI Executive Council, Ames Research Center, December 14, 2000
58. Faithorn, Lisa, “NAI Collaborative Support Efforts: An Overview”, Presentation to Dr. Carl Pilcher, Special Assistant to Dr. Ed Weiler, Associate Administrator for the Office of Space Science, Ames Research Center, February 14, 2000
59. Faithorn, Lisa, “The NASA Astrobiology Institute: An Experiment in Establishing a “Virtual Community”, RIACS Seminar Series, Ames Research Center, April 5, 2001

II.B.3.g Future Plans

- Creation of an over-all vision for the communication/collaboration dimensions of the virtual institute involving key stakeholders from the NAI community, the technology community and from the sociological research community
- Continuation of research on desktop communication and collaboration solutions, hardware and software, resulting in an implementation plan for NAI community-wide desktop solutions.
- Selection of specific scientific collaboration projects identified as needing NAI support by NAI members through the Needs Assessment, with the intention of collaborating with colleagues from Code I and other Ames colleagues, to plan and implement solutions.

II.B.4 BEACON: Bio-Evolutionary Advanced Concepts for NASA

II.B.4.a Task Summary and Overview

BEACON (Bio-Evolutionary Advanced Concepts for NASA) is being developed as a think tank where NASA, universities, and industry can collaborate to conceive the next generation of bio-inspired research and technology for NASA missions.

BEACON will bring together cross-disciplinary teams from NASA, universities, and industry to explore future directions for NASA. BEACON will address NASA’s need for more effective cross-disciplinary integration: while NASA teams analyze existing work processes, e.g. for mission control, insufficient attention has been paid to the biggest challenge faced in designing NASA missions — solving new problems as they arise and enabling innovation. Innovation entails

- hypothesis generation, theory-building, and new technology development on the interface of biology, astrobiology and information science and technology;
- assembling teams to troubleshoot and collaboratively solve unpredicted problems as they arise;

- supporting teams, both co-located and working in distributed CPSEs (collaborative problem-solving environments) or webtanks (think tanks on the web);
- refining design method and tools to support this activity;
- developing systems not only to guide convergence and synthesis within teams, but also to coordinate integration across teams;
- knowledge management and collaborative methods and tools to extend the above capabilities, and to document and assess the effectiveness of the think tank.

II.B.4.b RIACS Staff

Zann Gill

II.B.4.c Project Description

BEACON will provide a context and method to generate and incubate innovative concepts involving NASA researchers and university collaborators in cross-disciplinary project and program development and engage a broad visionary community in the design of NASA missions. To accomplish this end BEACON will be

- a vehicle through which NASA can achieve breakthroughs at the disciplinary interface of information science and technology, biology, and astrobiology;
- a neutral ground for universities and industry to collaborate with NASA on advanced concepts and collaborative R and D that can spawn new NASA Institutes;
- a vehicle to support design of new bio-inspired IT candidate technologies for the Mars 07, astrobiology, and other missions;
- a way to accelerate “the four *I*’s of BEACON”:
 - basic inquiry into scientific objectives of NASA missions, such as the origin and identification of life,
 - process and technology innovation to meet scientific objectives, such as earth analog missions, which requires better communication across science and technology,
 - insertion of new, bio-inspired theory, processes and technologies into NASA missions, which entails bringing cross-disciplinary design and planning teams together,
 - project integration through improved communication and knowledge management.

II.B.4.d Accomplishments during FY2001

Zann Gill developed a programmatic approach for a think tank, which is documented in the plan for BEACON. The process of developing the plan entailed discussions with a range of leaders, both internal and external, with the objective of identifying their priorities and enlisting their participation in the development of this proposed think tank. Part of this task entailed associated research relevant to the development and operation of BEACON, including

- Background Research on comparative programs, centers, and thinking in this field;

- Applied Research on how to support the function of BEACON, i.e. how to enable cross-disciplinary teams to generate advanced concepts and integrated plans.

This included background research on the process of innovation in the commercial sector, exploring how innovative companies explore new concepts and methods.

In addition, to pilot test ideas for an associated webtank (think tank on the web) Gill initiated a collaboration with the SETI Institute on development of SETI's cross-disciplinary high school science curriculum (physics, chemistry, biology, evolution of technology), *Voyages Through Time*. The curriculum shows how the concept of evolution applies across these disciplines and integrates them. The requirements of the fourth *Evolution of Technology* module offered a chance to develop and pilot test a collaborative web environment that can later be adapted, augmented, and extended for the NASA think tank. She has begun the design of that collaborative web environment, or webtank (think tank on the web), which students can use both as an information archive and to support collaboration on their own design/ invention projects.

II.B.4.e Publications and Presentations during FY2001

II.B.4.e.i Publications

93. "Webtank Design: intranet support for collaborative problem-solving", Systems, Social, and Internationalization: Design Aspects of Human Computer Interaction vol 2. edited by Michael Smith and Gavriel Salvendy. N.J.: Lawrence Earlbaum Assoc. 2001. pp. 292-296. (Also presented at HCI International 2001, see presentation 63 below)
94. "Simulating the Future: Computing and Speculation", chapter in the book *Journeys into Space: Quest for the Origins of Life*

II.B.4.e.ii Presentations

60. "Guided Design of Smart CPSEs (Collaborative Problem-Solving Environments)", SmartSystems 2000: International Conference for Smart Systems and Robotics for Medicine and Space Applications, NASA Johnson Space Center, September 6-8, 2000, Houston, Texas.
61. "Concept for a Web-based Exhibition Environment", Contact 2001 Conference at the Hotel Santa Clara, March 3, 2001.
62. "Webtank Assessment: Performance in Web-based Collaborative Learning Environments", Human Systems 2001: Exploring the Human Frontier, A Conference on Technologies for Human Factors and Psycho-Social Adaptation in Space and Terrestrial Applications, Houston, Texas, June 20-22, 2001.
63. "Webtank Design: intranet support for collaborative problem-solving", HCI International 2001 in New Orleans, 5-10 August, 2001.
64. "Webtanks: Tools for Learning by Design", Siggraph 2001 Conference in Los Angeles, 12-17 August 2001.

II.B.4.f Future Plans

- Revise and augment the Implementation Plan for BEACON. This plan will show how BEACON can serve a critical function for NASA, fostering NASA/ university/ industry partnership and providing an attractive middle ground between NASA and industry that can retain outstanding NASA talent and reduce the “brain drain to industry.”
- Initiate development of BEACON’s first theme.
- If appropriate, identify and enlist partner(s) for a first activity of BEACON.
- Design and manage development of a cutting edge interactive BEACON website.
- Develop a start-up strategy for BEACON.
- Continue to carry out research and to write, publish, and present on topics related to BEACON.

II.B.5 Information Management Tools to Enable Program Intelligence

II.B.5.a Task Summary and Overview

The matrixed nature of NASA's line and program management promotes a healthy cross-fertilization of research technologies and expertise, but at the same time creates many gaps in accountability for research objectives and appropriate management of resources. Ames Research Center management has recognized the need for information management tools and methods to align the program and line management functions in order to enhance the probability for success of research objectives.

The objective of this work is to provide novel information management tools and methods that: promote increased accuracy in project and program tracking, provide a simple method for analyzing historical program data, integrate program objectives with line accountabilities, visualize trends in research progression and the management of research resources, and enable informed decision-making at higher levels of center management.

II.B.5.b RIACS Staff

Linda R. Andrews

II.B.5.c Project Description

This task is to provide leadership and expertise in the areas of project and program information management, and the design of tools to allow analysis and trending of this information. The overall vision is to introduce novel tools (both internally-developed and COTS) that significantly enhance NASA's ability to evaluate the status of projects and programs. The goal is to yield greater mission/program success, in incremental steps.

Emphasis is placed on understanding the fundamental nature of the research division and programs included in the scope of the initial effort, with an eye toward expanding the use of tools and methods throughout the agency, as appropriate. The “program intelligence” tools will be demonstrated against documented mission failure analyses to test whether deployment could have eliminated critical failure events. Partnerships will be established with personnel both within Ames and at other NASA centers to ensure that a migration path exists for any technology developed.

II.B.5.d Accomplishments during FY2001

This task was initiated in June 2001. The following has been accomplished in the four months.

A Program Intelligence Tool (PI Tool) has been designed in module structure allowing for immediate achievement of some project goals, with planned increases in functionality in '02 and beyond. The first module of this tool is an electronic, web-accessible program reporting system which allows users to input status of technical, schedule and budget issues for L1, L2, L3 or L4, based on user privileges. These inputs are then represented in a graphic schedule of milestones, and are query-able by all privileged upper managers. This module has been fully developed and implemented and currently has 15 beta-test users in the ECS (Engineering for Complex Systems) program at Ames.

The design of the tool is a result of multitudes of data acquired through discussion with potential users, a literature review of applicable NASA guidelines, requirements, and documentation by past center directors, and the experience that comes with working at the center for nearly a decade. Potential users interviewed include: division, directorate, and technical area managers, resource managers, operations managers, contract negotiators and staff, ISO compliance representatives, program managers at all levels of accountability, researchers performing on program milestones, and managers of research centers outside of NASA seeking to solve similar problems, including HP Labs, Lawrence Livermore National Lab, and Schlumberger knowledge management staff.

Additional NASA programs have already expressed interest in the PI Tool (including AvSP and IS programs) without any marketing efforts underway. In reality, the challenge will be to maintain a small, core group of users to complete a satisfactory beta-test period before further release.

In addition to the program reporting, tracking and archiving functionalities described above, a new effort is underway to begin to tackle the issue of risk identification. As NASA struggles to recover from several highly-publicized mission failures, much attention has been given to risk mitigation and management strategies. However, it is critical to first have the ability to identify risks before mitigation strategies can be useful.

To this end, I have chosen several highly complex, high-risk systems for analysis and research (the results of which may integrate into a module of the PI Tool). I have engaged researchers at the Center for Nonproliferation Studies at the Monterey Institute, the NAI center at Lawrence Livermore National Laboratory, the Earth Sciences team at Ames, and Stanford's Management Science & Engineering faculty specializing in Decision and Risk Analysis, to participate in collaborative research.

II.B.5.e Future Plans

FY02 will be spent further developing the scope of collaborative research on risk analysis and identification, and proceeding with research in the areas determined to be most applicable to NASA. Additional design modules of the PI Tool will focus on taking the existing automated program milestone reporting and tracking system and linking it to a line management description of the resources required to fulfill program objectives.

II.B.6 Information Management Requirements Study

II.B.6.a Task Summary and Overview

A study, jointly supported by NASA, NSF, and DARPA, is being conducted into the requirements for technology advances to achieve the needed capabilities for information management in domains of particular interest to sectors of the government. This study will be carried out by a panel of

experts in the related disciplines, and will produce its results within one year of the start of the effort.

II.B.6.b RIACS Staff

Barry Leiner
Linda Andrews

II.B.6.c Project Description

Advances in networking and computing technologies have fundamentally changed the problem space for information management and its various application domains. Before the availability of high bandwidth networking, networked high performance computing, and large scale storage, the major problem was the accessibility of information. Information was often stored in forms that were not easily available, and finding and retrieving the required information was difficult.

The technology advances have changed this situation. If information is on a networked computer, it can be accessed and retrieved (assuming appropriate access control permissions.) Large amounts of data can be searched and indexed, and queries can be done against such indexes to find relevant data.

The new problem space is a direct result of these advances. So much information is accessible and retrievable that the challenge is finding the right information. (As an example, a “Google” search for the term “information management” returns 791,000 hits.) Information is stored in various formats, and the user may not have the means for dealing with the obtainable data. Turning data into actionable and coordinated information requires structure, and the large and varied amounts of information on the network make structuring that information difficult. Preserving information as the underlying infrastructure evolves becomes problematic, particularly given the amount of information being generated.

Yet information management technologies are having and will have major impact on a number of application domains of interest to multiple government sectors, such as coalition mission operations, logistics support, scientific data management, and digital libraries. Each of these application domains (and others) of information management have their own requirements as we move forward. However, there is considerable overlap of requirements, and investments in one area can have significant benefits to others.

This study will take an integrated look at the various application domains of information management (digital libraries, mission operations, logistics and maintenance databases, scientific data management) to understand the common and unique requirements of the domains, and the state of the art of the technology that can support such requirements.

II.B.6.d Accomplishments during FY2001

This task was initiated in July. Since then, we have:

- Arranged for joint support of study by the three agencies – NSF, DARPA, and NASA

- Recruited three study co-chairs from the research community. These co-chairs are both “computer science savvy” and familiar with various application domains of information management.
- Recruited approximately 20 study panelists from the community.
- Set up a PostDoc folder to support the study through document sharing and email.

II.B.6.e Future Plans

The study kickoff meeting will be held 29-30 November 2001 at NASA Ames. The intent is for the bulk of the effort to be conducted online (through email and document sharing techniques), with the results available by the end of FY2002.

II.C High Performance Computing and Networking

Advances in the performance of computing and networking continue to have major impact on a variety of NASA endeavors, ranging from modeling and simulation to data analysis of large datasets to collaborative engineering, planning and execution. RIACS and NASA collaborate in several areas as described in the following sections.

II.C.1 NASA Research and Education Network

II.C.1.a Task Summary and Overview

The NASA Research and Education Network (NREN) project conducts research to enable the infusing of emerging network technologies into NASA mission applications. The NREN testbed peers with Next Generation Internet (NGI) testbeds sponsored by other Federal agencies and with the university-led Internet2 testbed to provide a nationwide platform for conducting network research and for prototyping and demonstrating revolutionary applications. Emerging technologies will enable new methodologies for achieving NASA science, engineering, and education objectives. RIACS provides support for the NREN Project at NASA Ames, including conducting basic networking research, participating in projects to develop new networking technology and revolutionary network applications, and assisting with software engineering and network performance engineering. For more information about the NREN Project see <http://www.nren.nasa.gov>.

II.C.1.b RIACS Staff

Marjory Johnson
Jerry Toung

II.C.1.c Project Description

M. Johnson is NREN Associate Project Manager. J. Toung is a member of the NREN applications and research group, specializing in network software engineering. Components of the RIACS task include assisting in the formulation of NREN plans, participating in specified research projects for the development of new networking technology, interfacing with the university research community, participating in development of revolutionary network applications, and publishing and presenting results at conferences.

II.C.1.d Accomplishments during FY2001

- NREN Mobile Networking Workshop
NREN hosted a workshop entitled “Mobile Terrestrial and Space Networking: Supporting the Scientific Community” in June 2001. Mobile networking will enable exciting new paradigms for NASA science and engineering, enhancing support for missions that extend into remote areas where it is not economically feasible to create a permanent wired communications infrastructure. NREN’s vision for the future is seamless integration of

mobile networking technologies (including satellite communications, wireless networking, and sensor networks) to provide anytime, anywhere networking throughout the universe. Specific objectives of the workshop included:

- Characterize the various mobile/wireless/satellite technologies that are capable of supporting applications involving high-resolution multimedia
- Examine how heterogeneous networks can be integrated to form a seamless end-to-end path
- Identify how scientific applications will be enabled and enhanced by mobile terrestrial and space networking

M. Johnson was general chair of the workshop. The final report of the workshop is located at <http://www.nren.nasa.gov/workshop/workshop6.html>

- Network Quality of Service Monitoring

J. Toung is designing and developing software for a network monitoring tool called PCMon. PCMon measures throughput of individual traffic flows, in contrast to traditional tools which measure aggregate bandwidth. Hence, PCMon enables measurement of the effectiveness of various approaches for achieving network Quality of Service (QoS), e.g., assigning preferential treatment to specified traffic flows across a network.

Previously PCMon was demonstrated across the NREN wide-area testbed at OC-3 traffic rates. In FY01 a data storage and retrieval capability was added to PCMon and demonstrated across the NREN wide-area testbed. In addition PCMon was upgraded to enable traffic measurement and monitoring of individual traffic flows at OC-12 speeds. A September 2001 demonstration verified data collection over OC-12/gigabit Ethernet links in a local laboratory environment.

- Project Support

- M. Johnson played a key role in planning future research directions for NREN as part of the Computing, Information, and Communications Technology (CICT) Program, a new program beginning in FY02.
- M. Johnson rewrote the research, applications, and workshop sections of the NREN web site (<http://www.nren.nasa.gov>), as part of a redesign of the site.
- M. Johnson is member of the LSN Network Research Team, which coordinates research activities among the Federal agencies participating in the Next Generation Internet initiative.
- M. Johnson manages NREN research grants to universities, working with the PIs to integrate their research with on-site NREN activities. An FY01 highlight of these grant activities has been the development of TCP protocol modifications at Georgia Tech and UCLA, aimed at enhancing application performance over satellite and wireless links. These new protocols are being tested as part of agency testbed activities focused on selecting protocols for space networking to support NASA missions.

- Other Activities

- M. Johnson served on a Federal networking panel at the 2001 Symposium on Applications and the Internet in January 2001.
- M. Johnson was a member of the organizing committee for the Federal Large-Scale Networking (LSN) workshop on New Visions for Large-Scale Networking, March 2001. The purpose of the workshop was to generate ideas for the Federal agencies' future networking research program.

II.C.1.e Publications and Presentations during FY2001

II.C.1.e.i Publications

95. Tang, J., Morabito, G., Akyildiz, I., and Johnson, M., "RCS: A Rate Control Scheme for Real-Time Traffic in Networks with High Bandwidth-Delay Products and High Bit Error Rates," *Proceedings of IEEE Infocom 2001*.

II.C.1.e.ii Presentations

65. Johnson, Marjory, "Networking at NASA," 2001 Symposium on Applications and the Internet (SAINT), San Diego, CA, January 2001.
66. Johnson, Marjory, "Science, Technology, and NASA," New Mexico High School Supercomputing Challenge Summer Teaching Institute, Socorro, New Mexico, June 2001.
67. Johnson, Marjory, "NREN Workshop on Mobile Networking," Workshop on Emerging Communications, Networks, and Architectures Technologies for NASA Enterprises, Cleveland, Ohio, August 2001.

II.C.1.f Future Plans

- Networking technologies that will be the focus of NREN activities next year include QoS and QoS middleware, measurement and monitoring, and mobile networking. A new NREN effort next year will be coordinating agency testbed activities to analyze protocols for space networking.
- NREN grant activities will focus on QoS adaptive middleware and integration of this technology into an appropriate NASA application.
- Future PCMon activities include modification to enable measurement of DiffServ and Multicast traffic flows, development of advanced user interface and data archival systems, and installation of the tool in the NREN wide-area network testbed.

II.C.2 Network System Support

II.C.2.a Task Summary and Overview

This task is to assist the network operations staff in operating the Ames Local Area Network efficiently and securely.

II.C.2.b RIACS Staff

David L. Gehrt

II.C.2.c Project Description

In performance of this task the RIACS personnel maintain and operate the authoritative name servers. This includes maintaining the security of the name servers including restricting access by unauthorized personnel and logging attempts to gain un authorized access to the name servers and other systems and networks administered by RIACS personnel.

II.C.2.d Accomplishments during FY2001

A major activity affecting the network at the Ames Research Center during the life of this task has been the establishment of three separate Physical networks designated Public, Private and Open. Each of these networks is isolated from the Internet and other ARCLAN networks by a firewall and the Ames DMZ and possibly by an additional firewall. The three new networks each have access regulated by their own set of security rules, and ultimately all networked computers and networked peripherals will be attached to one of these networks. This reconfiguration requires the readdressing of virtually all of the nearly 20,000 IP addresses used on the Ames networks. The changes are being made building by building through the use of a script developed a part of this task. This script allows the bulk conversion of the addresses for an entire building or set of buildings. As a result of this process errors are reduced and the workload on the Network Staff has been significantly reduced.

Under this task the hardware and configuration of the authoritative name servers has been modified. Two new hardware systems were brought on line each using an open source operating system and providing a significant performance improvement. The generation of the DNS tables for the Center which used to take nearly two minutes now takes about six seconds. The configuration changes involved upgrading the BIND servers to version 9.x from version 8.x. And the use of a hidden master name server configured to not respond to recursive queries. Each of the name servers is configured to permit access over the network only to a very small set of authorized users and then only through the use of SSH.

Unauthorized attempts to access any of the name servers are logged to a remote system and reported to the system administrator for investigation. Unauthorized attempts to access ARCLAN systems and networks reported to the administrative personnel and of a serious nature are reported to the Center Computer Security staff for their action. This logging was enhanced this year including logging to a relational data base.

An ongoing effort is the assistance to Network Staff in the design of firewall rules to permit access from the ARCLAN Upgrade network while preserving network security.

II.C.2.e Future Plans

In the future it is planned to retire all the old authoritative name servers and replace them with new systems recently acquired by the Government. Additionally the DNS software will be maintained at the most recent and secure version.

II.D Applications of Information Technology

In addition to the areas of research outlined above, RIACS scientists and visitors have collaborated with NASA researchers in an interdisciplinary context to apply (and advance) information technology in a number of application domains, as described in the following sections.

II.D.1 Advanced Visualization and Collaborative Virtual Environments for Medical and Scientific Imaging

II.D.1.a Task Summary and Overview

Development of advanced 3D reconstruction and visualization techniques for cell biology and medical research, and collaborative virtual environments for interactive data analysis. This is a multi-project task oriented towards creating virtual reality technologies associated with biological models. Projects in 2001 included: Real-Time finite element modeling of physiological tissues, prototype design of immersive Virtual GloveboX, automated hand tracking, Distributed Virtual Environments.

Computer science research at the Ames Center for Bioinformatics is focused primarily on the development of advanced 3D reconstruction and visualization techniques for cell biology and medical research. RIACS staff provides technical leadership for all CS projects in the center. The primary project was the design and initial implementation of the NASA Virtual GloveboX (VGX), a virtual environment simulation tool for evaluating and training astronauts on biological experiment procedures. The VGX is a long-term project to develop a fully immersive environment for simulating animal surgeries and other biological experiments expected to be performed on the International Space Station. The VGX will be comprised of a virtual display covering the same physical dimensions of the actual Life Sciences Glovebox (LSG), and a set of haptic feedback devices for allowing interaction with the simulated biological data sets. The VGX will also be used for procedural training, and refresher training onboard the ISS prior to astronauts performing a specific surgical procedure. The VGX is an extension of the technologies developed in 1999 that comprised the Virtual Collaborative Clinic (VCC).

II.D.1.b RIACS Staff

Xander Twombly
Rei Cheng (until May 2001)
Andreas Frank (until Nov 2000)

II.D.1.c Project Description

- Design and refinement of the Virtual GloveboX display environment. Design and creation of a super high-resolution display system used to emulate the working space of the Life Sciences Glovebox.

- Visual hand tracking. Basic research to track exact hand position and joint orientation of a user's hands in the VGX using multiple video cameras, and refinement of camera calibration methods for increased spatial accuracy when estimating the position of common points from multiple video streams.

II.D.1.d Accomplishments during FY2001

- Virtual GloveboX (VGX) display system - redesign and prototype construction of the VGX display system. Display system is a modular façade design to allow maximum flexibility in creating the physical dimensions of the glovebox workspace, and incorporates visual tracking systems and force-feedback devices.
- PC display cluster for VGX display - Initial development of a dual PC graphics system to display stereo images through two high resolution graphics cards in a Windows operating environment. This linked PC system surpasses the available output from the benchmark Silicon Graphics Infinite Reality2 (IR2) graphics system by 300%, and costs less than 1/100th the cost of an SGI Onyx2 with IR2 graphics systems.
- Visual hand tracking – software implementation of a multi-camera tracking system for viewing dynamic object in an enclosed space. Continued development of algorithms for quantifying orientation and position of dynamic (jointed) objects from the simulated video images has been implemented using adaptive neural networks. Refinement of multi-camera calibration techniques for estimating spatial position of common points in multiple video streams.
- Further creation of virtual rat models - Extensive 3D surface model library of a rat has been created from a high resolution CT scan as a collaborative project with researchers outside of RIACS. Model includes segmentation of skin, bone, and major organs. All models have been generated in multi-resolution format for use on multi-platform visualization systems with varying hardware capabilities.

II.D.1.e Publications and Presentations during FY2001

II.D.1.e.i Publications

96. Frank, A.O., Twombly, I.A., Smith, J.D., Barth, T. Finite Element Methods for real-time Haptic Feedback of Soft-Tissue, Proc. The 2001 IEEE Virtual Reality Conference (IEEE-VR2001), Yokohama, Japan. In Press.

II.D.1.e.ii Presentations

68. Invited speaker: NASA Virtual GloveboX (VGX): Advanced Astronaut Training and Simulation System for the International Space Station, MMVR2001 (Medicine Meets Virtual Reality) Newport Beach, CA Jan 2001
69. Seminar in Ultrasound: Applications and Implications in Human Spaceflight, Johnson Space Center, July 2000. Member of panel discussion on the development of distributed ultrasound systems.

70. Smith, J.D., Twombly, I.A., Bruyns,C., Wildermuth, S., Cheng, R., Boyle, R. NASA Virtual GloveboX(VGX): Training and Simulation for Biology Research Aboard ISS. (Abst.) SAE 2001.

II.D.1.f Future Plans

The focus of the Center for Bioinformatics has shifted from straight visualization to a more interactive technology. The RIACS staff is expected to continue leveraging previously developed virtual reality environments, and to further development of a simulation engine for real-time interactions with dynamic 3D models. The development of a highly functional version of the Virtual GloveboX is a top priority, both using rigid body simulation for procedural tasks (i.e., logistical testing of equipment placement and movement within the Life Sciences Glovebox) and dynamic body simulation for practicing surgical procedures. The emphasis will be placed on resolving some of the issues involved in the new display geometry, enhancements to the OpenGL graphics pipe to handle non-standard viewing geometries, and high performance network implementations of a remote graphics display server. Previously, a strong emphasis was placed on development of real-time finite element-based simulator of soft tissue dynamics for use in simulated surgery. These efforts have been moved to the NASA-Stanford National Biocomputation Center in a continuing collaboration on this project.

II.D.2 Integrated Human/Robotics Exploration & Astrobiology

II.D.2.a Task Summary

Increase USRA participation in the planning and execution of the Integrated Human/Robotics Exploration Program. Assist in the establishment of a HEDS Human Exploration Science Community to facilitate greater academia involvement in HEDS exploration efforts

II.D.2.b RIACS Staff

Lewis L. Peach, Jr. (USRA HQ)
Mike Duke (consultant)

II.D.2.c Overview

There is a growing awareness that the integration of human exploration and robotics space sciences goals and objectives will result in a stronger, more comprehensive and productive exploration program that will lead to a time-phased, balanced set of objectives to drive future robotics missions and enable human exploration beyond low Earth orbit. This requires the collaboration of two formally somewhat diverse communities, in the development of an integrated set of objectives and requirements, and in the participation of a process to implement these

II.D.2.d Project Description

- Overall lead for Major USRA/NASA Human-Robotic Exploration Study
- Member of various Mars Architecture Development Committees

- Member of International Mars Exploration Working Group (IMEWG)
- Member of Mars Exploration Program Analysis (Advisory) Group (MEPAG)
- Member of the Mars '01 Program Science Working Group
- Conducted Major NASA/USRA Human Enabled Science Workshop (Duke)
- Initiated and Supported NRC Study to Define Human Exploration Requirements
- Co-lead in the development of a program to effect collaboration between Russia and USA on Human Exploration (ISTC 1172)
- Formal Collaborator on Follow-on State Department Funded Russian Exploration Study (ISTC 2120)

II.D.2.e Accomplishments during FY2001

- Oversaw successful flight of the '01 Mars Robotics Mission HEDS Instrument.
- Co-lead for a series of workshops and technical exchanges between the Russian Space Agency and NASA to develop an understanding of the two countries' different approaches to human exploration, resulting in a final report (ISTC 1172, Jan.'01). .Co-led U.S. effort, as formal USRA Collaborator, in definition and planning for follow-on Russian Exploration Study, which has been approved for funding by the U.S. State Department (ISTC 2120)
- Participated in, and helped facilitate, an advisory process to establish an integrated set of robotic science and human exploration goals, objectives and investigations which are framing the robotic exploration of Mars for the next two decades. .Conducted major NASA/USRA Human Enabled Science Workshop, which brought together the planetary scientists, and human exploration communities to develop an understanding of the role that human explorers will play in enabling scientific discovery. Results of this effort have been used to formulate requirements for a NASA NRA that would (budget permitting) involve the academic community in this area of research. (Duke)
- Overall lead for a USRA/NASA Human Robotic Exploration study for NASA's Revolutionary Advanced Systems Concepts (RASC) Office at LaRC, which involved an RFI, conducted by NIAC, and a major Workshop at ICASE, to bring together top planetary scientist, human exploration engineers, roboticist, and innovative advanced concepts specialists and technologist to evaluate the potential advances in the human machine partnership of the future, determine the science that would be enabled by this partnership, and identify critical technologies which should be made to make these advances possible. (final report under development)
- Successfully advocated the creation of an academic outreach program that will facilitate collaboration between university students, and their faculty, with NASA's RASC Office at LaRC (RASC-AL).
- Successfully advocated, and supported NRC study to define critical human exploration requirements which must be validated robotically at Mars, prior to the initiation of human missions (NRC report, under development)

II.D.2.f Publications and Presentations during FY2001

Co-authored various Proceedings, Workshop Reports, and Requirements Documents resulting from the above activities.

II.D.2.g Future Plans

Continue these tasks as initiated this past year, with greater emphasis on:

- The development of a HEDS Science Community
- Stronger involvement of the academic community in these efforts (ongoing); and,
- Complete review and prioritization of the integrated set of exploration requirements (established with the NRC Study).

II.D.2.h Problems Encountered

- Mars Robotics Program re-planned following loss of Mars Climate Orbiter and Mars Polar Lander in 1999, resulting in loss of near-term flight opportunities for instruments selected for the '01 and '03 Mars Mission opportunities.
- NASA Budget uncertainties, resulting from recent development problems of the ISS.

II.D.2.i Problem Resolution

- Participating in the reformulation and execution of the Mars Exploration Program, continued involvement in the on-going Mars '01 Mission, overseeing completion of the various technical efforts to prepare for future flight opportunities, and continuing the development of a HEDS Science Community and incorporating these efforts with the integrated Human /Robotic Exploration Programs.
- Broaden the NASA's support for these efforts by furthering collaboration between additional, new, NASA sponsors, and members of the broader academic community.

II.D.3 Astrobiology Planning

II.D.3.a Task Summary and Overview

This task assists the Astrobiology Integration Office (AIO) in evaluating and setting programmatic objectives of the AIO. NASA Ames is the lead center for Astrobiology. Work involves planning, HQ and senior member interface, and collaborations with other Astrobiology offices and researchers at Ames.

This task also staffs the Executive Producer role for the Astrobiology Portal website <http://astrobiology.arc.nasa.gov>.

II.D.3.b RIACS Staff

Kathleen Connell

II.D.3.c Project Description

For over 15 years, NASA/Ames has explored the potential of "innovation at the intersection of disciplines" as a possible strategic thrust. In 1995 Connell, in conjunction with NASA collaborators, co- created a team at Ames which gave scientific structure to this organizing principle, in the creation of the discipline now known as astrobiology. This multidisciplinary program seeks to answer fundamental questions about the origin, evolution and distribution of life in the universe, and has become a major scientific thrust for the Agency. Other compelling opportunities have presented themselves to NASA and the university space community, as the 'biology century' is fully underway in 2001. Related to this powerful quest of seeking life in the universe is an emerging set of inquiries in the societal domain. Connell is a thought leader in this unfunded branch of astrobiology.

II.D.3.d Accomplishments during FY2001

- Increase of web traffic of 300%-400% since incumbent assumed management.
- Web portal redesign underway.
- Proposed Homeland Defense review for ARC contribution to terrorist crisis.

II.D.3.e Publications and Presentations during FY2001

II.D.3.e.i Publications

97. "Report on The Workshop, Societal Implications of Astrobiology" Final Draft complete and submitted for publication as a NASA Technical Memorandum.
98. Harrison, A., Connell, K., Schmidt, G., "Society and Astrobiology", accepted as lead story in Space Times, December 2001.

II.D.3.e.ii Presentations

71. Invited Speaker: United Nations, Vienna, Austria. Occasion of International Women's Day, "Societal Issues, Space Research, and the Condition of Women Around The Globe."
72. "Ethical, Legal, and Social Implications of Federal Research" August 21, 2001. Briefing for Alvin Toffler at NASA/ARC

II.D.3.f Future Plans

The AIO is maintaining a level of effort in executing the lead center function. The anticipated thrust is focused on greater collaboration with the other Codes.

II.D.4 Fundamental IT/Biology Planning

II.D.4.a Task Summary and Overview

Assist the Fundamental Biology (FB) chief in evaluating the policy environment for new biology initiatives.

II.D.4.b RIACS Staff

Kathleen Connell

II.D.4.c Project Description

The FB office is a level 1 HQ office resident at Ames, and responsible for executing the fundamental biology research program for NASA. Connell has proposed various planning and policy studies, and generally consults with the FB lead on a regular basis on a variety of programmatic topics. She is now a co-investigator with two team

Compelling opportunities have presented themselves to NASA and the university space community, as the 'biology century' is fully underway in 2001. FB is engaged in formulating several new initiatives which are focused on the studies of the genome in space, and life off of the planet or origin. The incumbent has helped formulate these initiatives.

II.D.4.d Accomplishments during FY2001

Initiated two studies, and acting in effect as co-investigator on each:

- Toffler and Associates "Value Domain Study"
- JMP Associates "Policy Environment Study"

II.D.4.e Future Plans

Execution of these studies and communication of results.

II.D.5 Earth Science Technology Office Support

II.D.5.a Task Summary and Overview

Serve as member of the Earth Science Technology Office inter-center team. Develop technology roadmaps and plans to support mid and far term earth science mission requirements. Communicate information and opportunities to Ames researcher. Serve as technical reviewer for various NASA Grants.

II.D.5.b RIACS Staff

Walt Brooks

II.D.5.c Project Description

The goal of this project is to insure that NASA Ames IT technology expertise is brought to bear on high level planning as well as specific technology projects initiated by the Earth Science Technology Office. The task requires weekly support of ESTO staff meeting, AIST staff meetings and biweekly ESTO TST meetings.

II.D.5.d Accomplishments during FY2001

- Served as Ames Representative to the Technology Strategy Team TST
- Organized Technology Strategy Team Site visit to ARC. Set up reviews and tours as well as dinner and invited speakers.
- Attended Site visits as part of ongoing reviews
- Represented ARC at Monthly reviews
- Served as ESTO Alpha West representative to the ESTO Office.
- Attended and communicated to Ames important results from Weekly staff and Monthly Office Reviews
- Support ESTO Monthly project reviews-work with Ames and Univ. PI to develop project status reports
- Develop Technology Roadmaps for the ESTO Office review and improve existing roadmap baseline
- Chaired session at Technology Workshop
- Served on special teams and task forces
- Member of Technology Assessment Working Group –responsible for development of TRL for S/W in support of technology Insertion
- Completed technical review of the Oregon Graduate University grant on VLSI Neurotechnology: Massively Parallel Computing for Autonomous Intelligence. Initial final report did not include sufficient details on the trade studies and modeling. Worked with the PI to generate a comprehensive final technical report.
- Worked with PI to improve flight test program for the Univ. Of West VA. Study “Airnet-remotely controlled B747 and B777”. Study developed Scale Models with on-board micro-processor based fault tolerant flight control systems. Additional flight testing required a no-cost extension. The tests were completed and the Grant Final Report was received and technically reviewed.
- Technology Oversight of Univ. of Montana Program “High Performance Correlators based on Hole Burning Technology.” Arranged for visit to ARC and review of program

II.D.5.e Future Plans

Continue as ARC member of the ETO Team

II.D.6 Integrated Thermal Protection

II.D.6.a Task Summary

The development of future Space Transportation Vehicles is dependent on the development of reliable thermal protection systems that require minimum refurbishment and repair. Instrumentation that can detect, diagnose and report defects in a timely manner is required. Repairs must be

performed easily and quickly on the ground and preferably automatically in Space. This research program will try to identify and develop technologies to fill these needs

The goal of this task is for USRA to establish a cooperative research program with the Thermal Protection Systems development and Information Systems/Nanotechnology research groups at Ames that will lead to the developments of Adaptive Intelligent Thermal Protection Systems for future Space Transportation Vehicle systems. This effort will define and evaluate potential approaches to detecting diagnosing and repairing thermal protection systems damage on Reusable Vehicles and HEDS Space Transportation systems. It will also provide consulting on thermal protection materials and systems and other relevant technical issues.

II.D.6.b RIACS Staff

Howard Goldstein

II.D.6.c Project Description

- Evaluate capabilities and the potential pay-off of coupling information Systems technologies with Thermal Protection System technologies and Nanotechnology to develop Adaptive Intelligent TPS (aiTPS). Define possible approaches to detect, diagnose and repair TPS damage due to impact from micrometeorites and other on orbit debris.
- Define and investigate new concepts for aiTPS including self-healing heat shield materials, novel approaches to instrumentation and new material/instrument combinations that will diagnose and self-repair after damage from any source.
- Participate in technical reviews for Code AS and AX and other NASA organizations and programs as requested. Consult with these organizations on program related to atmospheric entry technology.

II.D.6.d Accomplishments during FY2001 FY2001

A major part of my time during the reporting period was spent on the Stardust program review as a member of the review board. The review thoroughly evaluated testing and design of the Stardust heatshield. Recommendations for testing and analysis to verify the design were made. The results of the review were used in subsequent technical interchange meetings on December 12-13 with Lockheed Martin Astronautics personnel and JPL to answer their concerns about the vehicle design and implications with respect to design of the Genesis vehicle heat shield.

Subsequent to the Stardust review I have been participating in the Pica Arc Jet Test team helping to define and consult on tests to validate the Stardust design. The review and subsequent activities by the reviewers and the Stardust design team have resulted in a major revision/enhancement of the analytical model used to predict Phenolic Impregnated Carbon Ablator (PICA) performance. Significant improvement in the design and interpretation of arc jet tests of this class of heat shield have also been accomplished.

From April to December I contributed to an inter-center working group interpreting the performance of the Russian German Inflatable Reentry and Descent Technology (IRDT) flight

experiment. I provided information and analysis of this technology to management at ARC, JSC and HQ. This technology is potentially applicable to space rescue vehicles and data return from Space Station.

I participated, as a member of the tiger team reviewing the X-33 plans for installation of the TPS system using the redesigned metallic hydrogen tank during January 01. The results of this review were reported to MSFC. Prior to that review I had been requested to chair a review of the thermal protection system, which I had begun to organize when the X-33 program was cancelled early this year.

I initiated a plan to develop a self healing thermal protection system for reusable launch vehicles such as the space shuttle and advanced reusable launch vehicles and prepared proposals for a code A DDF and a center wide DDF to fund the work. Both proposals were approved and research has been in progress since May 01 on the programs. This technology, if successful, could significantly increase the reliability of the TPS and therefore decrease the operations cost and turnaround time of future reusable launch vehicles.

In August I initiated an arc jet test program to evaluate the capabilities of Silicone Impregnated Reusable Surface Insulation for use as part of the thermal protection system for the Kistler K-1 reusable launch vehicle. This test program is ongoing at this time.

I was a member of the MER Aeroshell Preliminary design review board on February 12 and 13. One of the recommendations by that board was that there be a more detailed review of the Thermal Protection System before the CDR. I was a member of the Peer review board for MER TPS on May 10 Both review boards made recommendations for improvement of MER project but concluded that the overall project was well run and should be successful.

During the year I have consulted on a variety of programs including RLV Gen 2 and Gen 3, X-33, X-34, TSTO concept, Mars missions, and on various heat shield materials and their performance with colleagues in codes AS, ASM, AX, NASA HQ, and several aerospace companies, From July through December I acted as a consultant to Aerospace Recovery Systems (ARS) on thermal protection of inflatable reentry bodies. I provided background information on NASA development of flexible ceramic heatshields and helped define a research program with ARS and Aerotherm Corp. to develop the heat shield materials for the inflatable concept. I have also reviewed numerous oral presentations and written papers as requested.

II.D.6.e Future Plans

I will continue to the program goals as originally defined with emphasis on the research program on self healing thermal protection materials. I will support development of the Kistler K-1 vehicle by completing the arc jet test program and as a consultant to Ames Code A Personnel and to Kistler Aerospace as required. I will also spend more effort on evaluating the payoff of coupling Information Systems Technologies with Thermal Protection system Technologies and Nanotechnology.

II.D.7 Multi-institutional Collaboration on Research, Development, and Demonstrations for Natural Hazards Impact Reductions

II.D.7.a Task Summary and Overview

This project facilitates collaborative research and development between NASA and non-NASA organizations on natural disasters and related technologies, demonstration projects, and model development and validation. This activity complements and supports research and technology development in the Earth Sciences and the Information Sciences and Technologies at Ames Research Center. The potential applications of remotely sensed data from NASA satellites and aircraft to mitigation of natural disasters are investigated.

The capabilities to acquire, process, and distribute data from multiple sources, including satellites and both piloted and unpiloted aircraft, to mitigate the scope and severity of natural disasters have continued to expand rapidly. The Earth Sciences Division (ESD) at NASA Ames Research Center has conducted extensive disaster-related research and technology development, particularly on fires and floods for more than a decade. There has been rapid growth in the capabilities of information and communications systems to process large volumes of data, to extract actionable information, and to distribute and visually display the information to the user communities. These growing systems capabilities provide new opportunities to develop and implement the needed technologies to conduct the research and related technology demonstration projects to reduce the large fiscal and human impacts of natural disasters. The national costs of natural disasters from 1992-1997 were \$54 billion dollars per year, with about 10% of these costs occurring in California.

II.D.7.b RIACS Staff

Linda Andrews
Richard G. Johnson (Consultant)

II.D.7.c Project Description

This project formulates, structures, and recommends architectural and programmatic approaches for collaborative disaster-related programs and information exchanges between the Ames Earth Sciences Division, and federal and state agencies, local and regional government, industries, not-for-profit organizations, and universities.

This project also reviews and assesses the applicability of advanced information systems and wireless communication systems for near-term and future research and development activities related to natural disasters.

II.D.7.d Accomplishments during FY2001

This activity has focused primarily on formulating and structuring potential disaster-related programs for collaboration between the Ames Earth Science Division (ESD), the Information Sciences and Technology Directorate, and other non-NASA partners, including RIACS.

Briefing materials were prepared and a series of meetings held with the ESD Chief, Deputy Chief, Ecosystems Science and Technology Branch Chief, and the RIACS Director to explore Disaster Infosphere concepts and architectures that were focused explicitly on direct access to disaster-related information by all users. This information-centric approach is intended to provide rapid access with minimum user constraints to dynamic information that disaster managers and other users require to make effective decisions before the disaster-related information degrades in value or becomes totally obsolete.

A reimbursable Space Act Agreement between NASA Ames Research Center (ARC) and the California Resources Agency has been facilitated and prepared in collaboration with the ARC Earth Sciences Division. This agreement is for collaboration on research and development, testbeds, and user demonstrations relevant to California resources, disasters, and natural and human-produced environments. The two initial projects structured and defined for this agreement are the Disaster and Environmental Infospheres (DEI) Project and the Data Server Utilization Testbed Project. The DEI Project is structured to use information provided by NASA, State of California, and other sources to demonstrate a prototype environmental infosphere that will enable collaborating user communities to effectively access and utilize large and diverse data bases to significantly improve the collaborative research process by use of the infosphere. This project will also develop and define strategic approaches and a plan for a prototype disaster infosphere for wildfires and will use a framework based on a collaborative program to utilize a long-duration Uninhabited Aerial Vehicle (UAV) for identifying and monitoring lightning-induced fire in remote areas. An initial research focus will be on low intensity smoldering fires in the Sierra Nevada Mountains.

II.D.7.e Future Plans

The plan is to continue the project into FY02 along the same lines but at an increased scope of effort.

II.D.7.f Problems and Possible Resolutions

The effective acquisition, development and utilization of large and diverse databases by a large number of diverse users remains a challenging problem. The development of new approaches and appropriately monitored multiple testbeds to access effectiveness is needed.

II.D.8 AeroSpace ExtraNet Data Sharing

II.D.8.a Task Summary and Overview

The current aerospace environment consists of thousands of independent entities: manufacturers, airlines, airports, service providers, research organizations, and government agencies. There does not exist a common architecture for networks, data formats, and application interfaces. Many operational systems have been in place for over 30 years. Because of the lack of a strategic aviation and aerospace information infrastructure architectures there are thousands of incompatible data repositories, network systems and applications. These “islands” of incompatibility not only

exist between organizations, but even within organizations such as air carriers and government agencies where departments are unable to efficiently share key information between maintenance, operations, and management, etc.

The extreme fragmentation of data and application non-interoperability has prevented the U.S. from developing comprehensive, system-wide applications that can monitor, track, and evaluate the overall performance of major components in the National Airspace System. The lack of comprehensive architectures not only has prevent aerospace organizations from developing system-wide applications, but it has also limited the ability of commercial third-party information technology companies to apply their extensive resources against this environment (as compared to the financial, medical or chemical industries for example).

II.D.8.b RIACS Staff

David Maluf

II.D.8.c Project Description

The objective of the AeroSpace ExtraNet AEN Data Sharing project is to develop the infrastructure to support a System-Wide Monitoring capability of the National Airspace System and to prototype Enterprise Safety applications that leverage that Infrastructure.

The extreme fragmentation of data and application non-interoperability has prevented the U.S. from developing comprehensive, system-wide applications that can monitor, track, and evaluate the overall health and performance of major components in the National Airspace System. The lack of comprehensive infrastructure not only has prevent aviation organizations from developing system-wide applications, but it has also limited the ability of commercial third-party information technology companies to apply their extensive resources against this environment

The Data Sharing project prototyped cutting-edge information technologies to support the evolving aviation industry NAS architecture. Key middleware technologies will help integrate the data and application interfaces by providing common machine readable handles to data and application services. The middleware components coupled with next generation physical network connectivity to key data sources (airline operations, FAA flight information, maintenance and manufacturing data) will provide the core elements that will help support enterprise-wide systems and applications.

- Remote Tower Sensor System – refinement of proof-of-concept prototypes at: San Francisco Airport, San Carlos Airport, Half-Moon-Bay and the Seattle Airport. The deployment of next generation RTSS.

To fully conduct research that will support the far-term concepts, technologies and methods required to improve the safety of Air Transportation a simulation environment of the requisite degree of fidelity must first be in place. The Virtual National Airspace Simulation (VNAS) provide the underlying infrastructure necessary for such a simulation system. Aerospace-specific knowledge management services such as intelligent data-integration

middleware will support the management of information associated with this complex and critically important operational environment. This simulation environment, in conjunction with a distributed network of super-computers, and high-speed network connections to aircraft, and to Federal Aviation Administration (FAA), airline and other data-sources will provide the capability to continuously monitor and measure operational performance against expected performance. The VNAS will also provide the tools to use this performance baseline to obtain a perspective of what is happening today and of the potential impact of proposed changes before they are introduced into the system. National Airspace Simulation (NAS) - A capability for evaluating future concepts for the Air Transportation System is being developed and has been demonstrated for integrated aircraft models including: engines, wings, and landing gear.

- Virtual Iron Bird (VIB) Centrifuge Accommodation Module (CAM) with application to the Biological Research Project – development & demonstration of a prototype. The VIB CAM simulation features the integration of 3D models of the CAM interior, advanced information management and knowledge engineering tools, communications, and immersion technology to create a VIB for the CAM.

II.D.8.d Accomplishments during FY2001

- **Virtual National Air and Space Simulation.** The accomplished work done for the Virtual National Airspace System (VNAS) provides the underlying infrastructure necessary for large airspace simulation. Smart Simulation and intelligent information in conjunction with distributed network of super-computers and high speed network (information power grid) will provide the capability to continuously monitor and measure aircraft performance.
- **Remote Tower Sensor System.** The work done for the Remote Tower Sensor research focuses on developing virtual tower systems that integrate real-time airport data to support smart operations for towers and during low/zero visual operations. Image processing techniques were developed to aid automatically and in real time help airport towers operates under difficult weather (e.g. San Fransisco Airport). The Half Moon Bay deployment will benefit the airport to operate unmanned from the Future Flight Central.
- **Middleware development for information Management.** Middleware in the context of data sharing (vs. knowledge sharing) focuses on semi-structured data packets. This research was directed XML and wrappers. One end result, namely Netmark, of this research is currently disclosed to NASA and applied for a patent. This work has immediatly being set in use in NASA day to day operations.
- **Remote Engineering Help Desk (With Boeing Company).** To prototype advanced Information technologies To improve maintenance Operations. Technology Integration on focused COTS products to connect TWA MOC & Maintenance Hangars and Boeing Rapid Response Center and Ames Research Center to established a high fidelity collaborative Engineering.
- **Dimensional Surface Super-resolution from Multiple Images.** Super-resolution development for the system that takes multiple images as an input and produces 3D surface and Albedo coefficients as an output on a super-resolution scale. 3D surface reconstruction with shadows was achieved and occlusions with success from a theoretical and a functional system.

- **Intelligent Agent (with The Boeing Company).** This research is to develop middleware components to integrate and extend the capabilities of aviation legacy systems on a secure extranet to support:
 - Real-time aircraft and airport situational awareness and scheduling and planning functions
 - Maintenance and operations procedures enhancements.
 - Feedback data mechanisms to design/manufacturing models and simulators

II.D.8.e Publications during FY2001

II.D.8.e.i Publications

99. David A. Maluf, Peter Tran, Articulation Management for Intelligent Integration of Information, IEEE Systems Man and Cybernetics, Special Edition on Informartion Management 2001
100. Bill McDermott, David A. Maluf, Yuri Gawiak, Peter Tran, Secure Large Scale Airport Simulations Using Distributed Computational Resources, SAE conference, Seattle 2001.
101. Richard Papasin, Yuri Gawdiak, David A. Maluf, Christopher Leidich, Remote Tower Sensors Systems, SAE conference, Seattle 2001.
102. David A. Maluf, and al., Recognition, Generation, Fusion, Update and Refinement (RGFUR) Concept, ISAIRAS, Montreal, 2001.

II.D.8.f Other Accomplishments during FY2001

II.D.8.f.i Patents

- An efficient approach to handle Unstructured data in Relational Databases. (Disclosure Applied through NASA). Inventors: David Maluf, Peter Tran, Tracy La, Jenessa Lin.

II.D.8.f.ii Program Member

- Twelfth International Symposium On Methodologies For Intelligent System ISMIS01
- Conference on Computer Science and Information Technologies CSIT2001

II.D.8.f.iii Conference/Workshop Organizer

- SAE sponsor: 2001 Advances in Aviation Safety Conference
- The NASA/Boeing Workshop on intelligent Data sharing
- Workshop I on Knowledge Engineering for Design for Safety (Nov 2000)
- Workshop II on Knowledge Engineering for Design for Safety (Jan 2001)

II.D.8.g Future Plans

Future plans encompass the development of technologies that will dramatically reduce system/subsystem development cost and time. As well as provide a means for assessing and integrating multi-fidelity aerospace vehicle simulations.

II.E Visiting Students and Scientists

A major contribution made by RIACS is the sponsoring and hosting of visiting students and scientists from universities and industry.

II.E.1 Summer Student Research Program (SSRP-2001)

Nine undergraduate and graduate students, from universities across the country, were selected in this, the second year of the program. Three students returned from last year's program for a second session with the support of their mentors. They spent 10 weeks at Ames, teaming with NASA scientists on research projects in a variety of areas in IT, including automated planning and scheduling, natural language understanding, model-based autonomy for spacecraft and rovers, automated software synthesis and verification, visualization and collaborative virtual environments, and collective intelligence.

Toward the end of the summer, students were invited to submit a proposal to continue their research at their universities on their return. Ellen Campana from the University of Rochester was chosen to receive this continuing research awards. She will continue her research on using natural eye movements to improve spoken dialog system performance.

The following are descriptions of the research projects conducted by the SSRP participants.

II.E.1.a Reinforcement Learning for Autonomous Agents Adrian Agogino of University of Texas, mentored by Kagan Tumer

My work this summer focused on the problem of designing groups of autonomous agents that individually learn sequences of actions such that the resultant sequence of actions achieves a predetermined global objective. In particular, I was interested in instances of this problem where centralized control is either impossible or impractical. For single agent systems in similar domains, machine learning methods (e.g., reinforcement learners have been successfully used. However, applying such solutions to multi-agent systems often proves problematic, as agents may work at cross purposes, or have difficulty in evaluating their contribution to achievement of the global objective, or both. Accordingly, the crucial design step in multi-agent systems centers on determining the private objectives of each agent so that as the agents strive for these objectives, the system reaches a good global solution. This summer, I worked on a version of this problem involving multiple autonomous rovers, where the global objective was to collect the most resources. I employed concepts from collective intelligence to design the goals for each rover. I showed that reinforcement learning rovers using those goals outperform both "natural" extensions of single agent algorithms and global reinforcement solutions based on "team games". In an experiment with 80 rovers, the global reward performed poorly since each agent's signal was dominated by the noise from the other agents. The uniform division reward performed even worse, since it caused each agent to greedily extract resources at the expense of other agents. The "WLR" reward, which was based on an approximation of the individual rover's contribution to the global reward, performed far better than the other two rewards, since it kept the rovers from interfering with each other, and at the same time had a high signal to noise ratio.

II.E.1.b Enhancements to the Earth-Observing Satellite (EOS) Domain Model **Kristin Branson of UCSD, Mentored by Robert Morris**

My task this summer was to make the EOS Domain model more realistic. The EOS Domain models a constellation of Earth-Observing Satellites. The domain is modeled after the Landsat 7 satellite and its request procedures. Each satellite has a number of imagers, antennae, and a Solid-State Recorder (SSR). Scientists make requests that images be taken of specific locations. The locations are specified in terms of World-wide Reference System (WRS) Scenes. Each WRS Scene has a path and a row. Paths are similar to longitude, while rows are similar to latitude. WRS Scenes are convenient for our model because each satellite's orbit follows a simple route in WRS Scenes. The image requests can also specify a set of possible times at which the image can be taken, what part of day (night/day) the image can be taken in, what capabilities the instrument which takes the image can have, and which satellites can take the image. In order for a camera on a satellite to take an image, the camera must be pointing at the desired location. In addition, an instrument must have the correct capability to take an image. If an image request is of a certain type, the image must be recorded by the SSR while the image is taken. The SSR has a finite amount of storage, so data can also be transmitted from the satellite to a ground station the satellite is in contact with. This requires an antenna on the satellite be pointing at the ground station.

My enhancements to the model were as follows. I first provided a mechanism for representing the part of day (night or day). I next developed an over constraint for determining the camera and start times of requests from the WRS scene specification. I next provided a mechanism for representing different instrument capabilities. I next represented instrument duty cycles. I also implemented cross-track instrument pointing. I also developed a test generator for the EOS domain and tested the planner performance on the enhanced model.

II.E.1.c Gaze and Language: Using Natural Eye Movements to Improve Spoken Dialogue System Performance **Ellen Campana of University of Rochester, Mentored by Beth Ann Hockey**

People naturally make predictable eye-movements while comprehending and producing spoken language. These natural eye-movements, taken within their linguistic and real-world context, can be used to improve the usability and speed of spoken dialogue interfaces. This summer, I researched ways to integrate online eye-movement data with the RIALIST spoken dialogue interface and outlines future research in detecting miscommunications, improving reference production and resolution, and refining confirmation strategies that build on this integrated system.

Gaze and speech are two modalities that humans naturally use to communicate with each other when their hands are occupied. The system I have been working on in collaboration with my colleagues at Ames Research Center is the first computational system to be developed with the goal of integrating eye-movement data and speech in a natural way. Eye-movements that humans naturally make while producing and comprehending language are considered within their linguistic and real-world contexts. This offers potential for improvements to the dialogue system by providing information to the system that would not be available to speech-only systems

This summer I wrote a software component that handles input from a head-mounted eye-tracker, providing real-time eye-movement data to a spoken dialogue interface that is being developed at NASA Ames Research Center. This interface was developed so that human users could interact with a simulated version of the PSA. The real PSA is a miniature robot currently being developed at NASA Ames, which is intended for deployment on the Space Shuttle and/or International Space Station. It will be capable of free navigation in an indoor micro-gravity environment and will provide mobile sensory capacity as a backup to a network of fixed sensors. The PSA will primarily be controlled by voice commands through a hand-held or head-mounted microphone, with speech and language processing being handled by an off-board processor.

II.E.1.d Beating the Kalman Filter.

Matthew Deans of Carnegie Mellon, Mentored by Esfandiar Bandari”

My task was to implement and test several methods for localization and map building on the ATRV Jr. and, subject to its availability, on the K9 rover. This includes implementation of a simple feature detection and tracking system to identify and track landmarks as the vehicle moves, and porting the existing localization and mapping algorithms to NASA Ames rover testbeds, and incorporating the capability into the rover software architecture.

During my collaboration with NASA ARC, I contributed to simultaneous localization and mapping (SLAM) capability for planetary rovers, incorporating the algorithms into the Ames rover testbeds, and testing, modifying and demonstrating the system. This involved study of Linearization for Recursive Nonlinear State Estimation and specializes for linear model & Gaussian distributions

II.E.1.e Knowledge Base for Data Tracking.

Judah Ben DePaula of University of Texas, Mentored by Keith Golden

NASA receives a stream of data from resources including satellites, telescopes, and planetary rovers. The data must be processed and delivered to scientists in a timely manner which in some contexts, such as detecting severe storms, may mean less than a day. The data must also be archived for future reference. The terabytes of archived data are worthless unless the scientists that wish to use them are able to find what they need. Keith Golden is developing a system called IMAGEbot. The IMAGE stands for: Information Manipulation, Archiving, Gathering, and Extraction. The purpose is to manage the huge amount of data gathered by NASA. In the design of a data planner there needs to be a knowledge base that will contain all information known about the environment. It was my job to design and implement that knowledge base. I started by setting up an SQL database server, called Postgres, to store logical rules. IMAGEbot will address these problems directly by automating the scripting process. A researcher will be able to request information in a given format. This query will be passed to a planner, which will try to send a sequence of data-processing commands and a set of raw data inputs that will produce the desired result. IMAGEbot is written in Java so the JDBC libraries were used to interface the database to the rest of the source code. I also implemented routines to populate, and retrieve, information from the database.

II.E.1.f Heuristic Search for Model Checking Java Programs **Alex Groce of Carnegie Mellon, Mentored by Charles Pecheur**

Due to my efforts this summer, substantial heuristic search capabilities were added to JPF 2. It is now possible to search not just deterministic depth first order but processing states from a priority queue. A number of heuristic values are now built in to JPF, including:

- path length (for simple breadth-first search)
- number of times last branch has been taken (global or path based, summing over paths or persisting until next branch as orthogonal options)
- number of times a particular byte code instruction has been executed (also either global or path based)
- number of unblocked threads (for finding deadlocks)
- the amount of thread interleaving on a path (or globally)

The size of the queue can be limited (throwing away states that have the worst heuristic value first) and storing of states can be turned on or off. The heuristic search capabilities have substantially increased the efficiency of finding bugs with JPF 2.

II.E.1.g Temporal Logic Runtime Monitoring **Scott Johnson of Univ. of Wyoming, mentored by Grigore Rosu**

For my research project this summer, we used a finite trace Linear Temporal Logic(LTL) semantic to monitor program execution. Our system filters an annotated source code file. Annotations consist of atomic propositions, defined as Boolean expressions, and desired LTL specifications. These annotations are then expanded into a source code representation of a finite state machine corresponding to the given LTL specification. At the moment, the system can handle future time as well as past time LTL formulae. The system may be thought of as a subset of the commercially available tool, Temporal Rover, however, the source code that we generate is more efficient than that of Temporal Rover. This work may be see as experimental and background work for the development of scalable hybrid(i.e. runtime and static) analysis systems which would provide both developmental and runtime environments. Heavy formal methods, such as theorem proving and model checking, have shown to provide excellent coverage in verifying hardware and software systems, meaning they take into account all possible execution paths through a given system with respect to a given property. However these methods are not feasible when applied to large real life systems, due to the complexity of their algorithms. On the other hand, traditional testing techniques that have evolved with software engineering practices scale very well, but they are often ad hoc do not provide the coverage as seen with formal methods. The Runtime Verification community hopes to provide developmental, as well as runtime, environments that may be combined with other techniques to bridge the gap between the scalability and coverage tradeoffs.

II.E.1.h Making HCC Probabilistic **Jonathan Moody of Carnegie Mellon, mentored by Anupa Bajwa**

I designed and implemented two mechanisms for collecting output (in an abstract sense) from HCC. Also I implemented a script which invokes HCC some number of times. Any printed

messages that the model produces while running are redirected to a file. By embedding the special “sample” statement in the model, trajectories for all the sample runs can be collected and plotted. The second approach is an improved C - HCC interface, which allows a C program to (among other things) run multiple instances of the HCC interpreter simultaneously, and extract values of variables, compute a mean across samples, compute probability of an event across samples, etc. This improved interface is working, but not yet complete.

II.E.1.i Practical Data Analysis with AutoBayes
Kate Mullen of Bard College, mentored by Bernd Fischer

AutoBayes is a program synthesis system for the generation of data analysis programs from statistical models. The system is fully functional for a number of data analysis tasks. However, prior to my work this summer its capabilities had not been tested on real data. I located appropriate data sets for analysis and used the model-specification language of AutoBayes to create statistical models of the data. I then used AutoBayes and the model specifications to extract information of interest from the raw data. Documentation of my work now makes up the AutoBayes Manual of Example Applications in Data Analysis.

II.E.1.j Fault Identification on K9 Rover
Vandi Verma of Carnegie Mellon, Mentored by Maria Bualat

My research this summer centered upon methods to identify problems (“faults”) with the K9 rover. To do so we need to detect deviation from expected behavior and identify reason(s) for the deviation. The approach taken was to model normal and fault behavior and to track behavior with particle filter. Faults studied included faulty motors, stuck wheels, and faulty encoders. The utility based approach investigated in my summer research enables particle filter approximation of low probability high risk events. In fault identification we found that we had good representation that was non-parametric and simple approximation. The simulation results are promising.

II.E.1.k Learning and reasoning with Simple Temporal Problem with Preferences
Brent Venable, Univ. of Padova, Italy, mentored by Dr. Lina Khatib

The STP (Simple Temporal Problem) formalism is already used in some projects here at NASA. However it deals only with hard constraints and that means that it is useful only for problems where knowledge is crisp and precise. There are many environments, on the other hand, where regarding everything as either “allowed” or “not allowed” can be impossible or simply meaningless. For the former reasons a new framework has been proposed for adding flexibility to STPs, that is: Simple Temporal Problem with Preferences. This new type of constraint satisfaction problem allows to add preferences locally, to the time points involved in the constraints and globally rating the solutions. My task for this summer at Ames was to implement a Solver for STPPs and a Learning Module that would induce from global guidance local preferences. In the last part of my summer program I have worked in applying the things developed to a real-life NASA project. In fact it looks like this project can fit in as an optimization of resource consumption tool for the planner of the Mars Rover. During my stay here at NASA I have been supervised mainly by Lina Khatib, my mentor, who has given me an essential help both in choosing the problems on which to focus and in finding solutions for them. Robert Morris has helped me see

where my project could fit in, highlighting connections to other areas as scheduling and planning. Paul Morris has given some great ideas, that turned out to be essential in overcoming difficulties both in setting the conceptual basis and in the actual implementation.

II.E.1.1 Software Certification

Michael Whalen of Univ. of Minnesota, Mentored by Johann Schumann

My summer research was split into two different projects, both involving different aspects of software certification.

The first project, DO178B Qualification for ASE Tools, dealt with certification requirements for the avionics domain. The Automated Software Engineering (ASE) group at Ames has two code generation tools that have potential safety critical applications: AMPHION/NAV and AutoBayes. AMPHION/NAV can be used to automatically generate C++ code for performing navigation and position finding from a graphical description of the different sensors and their relationships. AutoBayes generates C/C++ code for statistical modeling from high-level statistical models.

The second project that I worked on this summer involved verifying certain properties about the code generated by AutoBayes. There are many desirable properties that we would like to check about a program. For example, we would like to know whether a program is memory safe or might attempt to take the square root of a negative number. We were interested in determining which, if any, interesting properties we could automatically verify using an external tool

We found several properties that had potential for automatic verification. We picked three safety properties: memory safety, variable initialization-before-use, and division-by-zero, and have attempted to show that that AutoBayes is safe with respect to these properties. To do so, we have used Hoare-style logic, which can be used to reason about the behavior of imperative programs. Along with the program, AutoBayes automatically generates a set of Hoare-style loop invariants as comments. These invariants are used by a theorem prover to attempt to show the safety of the program with respect to our chosen properties. We hope to eventually be able to gain a high level of confidence in the generated code by automatically verifying several of these properties, even if the code generator itself is not trustworthy.

II.E.2 Visiting Scientists' Research Project Descriptions

RIACS regularly sponsors and hosts visiting scientists from universities and industry to provide highly specialized expertise to various NASA projects. The following are descriptions of the research conducted by these visitors.

II.E.2.a Bjorn Sjogreen, Neil Sandham

Computational Fluid Dynamics – Helen Yee

II.E.2.a.i Research Description

Three research topics were addressed by this team:

- Construction of stable, efficient and low dissipative high order shock-capturing schemes

- Entropy splitting of inviscid flux derivatives for high order numerical simulation of compressible turbulence
- Multiresolution wavelet based adaptive numerical dissipation control for high order shock-capturing schemes

Our focus is on improving the speed, accuracy, and nonlinear stability, and minimizing the use of numerical dissipation in large scale computational aerosciences, computational astrophysics and astrobiology simulations without resorting to extremely fine grids and time steps.

II.E.2.a.ii Accomplishments

Our recently developed class of low dissipative high order schemes requires only a 10% increase in operations count over standard second-order TVD schemes for 2-D direct numerical simulations. Studies showed that higher accuracy was achieved with fewer grid points when compared with that of standard higher-order TVD, positive, ENO or WENO schemes. The results are published in [103-105].

II.E.2.a.iii Publications and Presentations

Publications

103. H.C. Yee, B. Sjogreen, N.D. Sandham and A. Hadjadj, "Progress in the Development of a Class of Efficient Low Dissipative High Order Shock-Capturing Methods," RIACS Technical Report 00.11, June, 2000, NASA Ames Research Center, 2000, also, Proceedings of the Computational Fluid Dynamics for the 21st Century, July 15-17, Kyoto, Japan, Notes on Numerical Fluid Mechanics, Vieweg.
104. N.D. Sandham and H.C. Yee "Entropy Splitting for High Order Numerical Simulation of Compressible Turbulence," RIACS Technical Report 00.10, June, 2000, NASA Ames Research Center, 2000, also, Proceedings of the 1st ICCFD Conference, July 10-14, 2000, Kyoto, Japan.
105. B. Sjogreen and H.C. Yee, "Multi-Resolution Wavelet Based Adaptive Numerical Dissipation Control for Shock-Turbulence Computations," RIACS Technical Report, October, 2000, NASA Ames Research Center.

Presentations

73. Colloquium, Dept. of Mathematics, Florida State University, Tallahassee, March 3, 2000 (Invited Presentation with full reimbursable travel)
74. Symposium on Computational Fluid Dynamics for the 21st Century, July 15-17, 2000, Kyoto, Japan (Invited Presentation)
75. National Taiwan University, Taipei, Taiwan, July 17-19, 2000 (Three Invited Lectures with reimbursable travel)
76. The First International Conference on CFD, July 10-14, 2000, Kyoto, Japan (Contributed Paper).

II.E.2.b Alessandro Acquisti*Brahms – Maarten Sierhuis*

As a Visiting Researcher with RIACS/USRA at the NASA Ames Research Center I have been working with Maarten Sierhuis and Bill Clancey on ‘Brahms’, an agent-based language used to model and simulate human activities.

Since January 2001 I have been involved in two projects. The goal of the first project was the production of a Brahms ‘Tutorial’ (text and computer code) to be used by researchers to learn the Brahms language. This project has been completed and the Brahms Tutorial is now used by other NASA and external modelers.

The second project involves the creation of a Brahms model of the crew’s activities onboard the International Space Station (ISS) and of the crew’s interaction with the Personal Satellite Assistant (PSA). As a part of this project, I completed the following tasks: I prepared an ‘ISS Model plan’ containing the information necessary to develop a Brahms model of the ISS; I developed a relational database of documents and sources of importance to that modeling; I co-authored a paper on the modeling of the Personal Satellite Assistant and its functionalities onboard the ISS, and assisted its presentation by Maarten Seirhuis at IJCAI 01; lastly, I have commenced the Brahms model of the International Space Station itself, modeling living and working areas inside various ISS modules.

II.E.2.c Jason Baldrige*XML Schemas for Typed Unification Grammars – Beth Ann Hockey*

Jason conducted research this summer on representations for typed unification grammars. His goal was to design a general representation scheme for such grammars, based on XML and XML schemas, and build translators to and from the most popular existing formalisms for typed unification grammars. His initial target was the representations used in Gemini (developed at SRI International, and used at RIACS) and LKB (Linguistic Knowledge Base) developed at CSLI at Stanford University. At a meeting at Stanford on Sept. 10th, he demonstrated the grammar developed for the PSA application in the Gemini formalism, translated to the XML representation, then translated to the LKB representation, and parsing sentences in LKB system. These work in re-using grammar representations, and thus enabling sharing of linguistic resources, is our first step in building an open-source natural language processing toolkit (OpenNLP/LEO). Our goal is to encourage collaboration between NASA, RIACS, and a number of universities (Stanford, Edinburgh, Berkeley, San Diego State, Delaware, USC, Oklahoma)

II.E.2.d Ralph Benzinger*Automatic Convergence Analysis – Bernd Fischer*

The main goal of the Automatic Convergence Analysis (ACA) project is to improve the performance of the code generated by the AutoBayes system, a powerful tool for automatic synthesis of data analysis programs developed by Bernd Fischer et al. at RIACS/NASA Ames. The ACA project is a natural continuation of my previous work on AutoBayes conducted during my SSRP appointment at NASA Ames the previous summer. By introducing manual convergence control mechanisms into AutoBayes, Bernd Fischer and I were able to significantly improve the reliability of code generated for iterative optimization problems. Our work clearly showed that the judicious choice of convergence criteria is paramount for optimal program performance. Based on our preliminary findings, we devised a research program to improve the quality of the generated code further through convergence control. We identified two particularly promising targets:

- Adaptive convergence monitoring, i.e. automatically synthesized, “smart” convergence criteria that are able to detect and counter insufficient convergence behavior; and
- Program optimization through post-synthesis running-time estimation, i.e. selection and combination of the most efficient algorithm schemata based on the expected worst-case running time of the synthesized code. A successful implementation of these goals also leads to interesting theoretical insights into the convergence behavior of common approximation algorithms.

II.E.2.e Marsha Berger

High resolution flow simulation – Michael Aftosmis

In collaboration with Michael Aftosmis, at NASA Ames Research Center, we are developing a set of tools for automated high resolution simulation of inviscid flow in complex geometries. Our approach is based on the use of Cartesian grids with embedded boundaries that are not aligned with the mesh. Two projects were the focus of my research this summer. We continued development of a highly scalable parallel flowsolver for Cartesian grids. Mostly due to improvements in the load balance in our domain partitioning algorithm, our flowsolver achieves speedups of 205 on 256 processors. The second project was development of an adaptive mesh generation algorithm for Cartesian grids. During the course of a calculation more resolution may be needed in some parts of the domain, and cells may need to be refined. The difficulty is in refining cells that intersect the geometry. This part of the adaptation algorithm is now complete; still remaining is the development of the mesh refinement criteria.

II.E.2.f Suhrit Dey

Computational / Mathematical Studies of the Dynamics of the Immune System with Applications to Breast Cancer – John Ziebarth

Lymphocytes are some of the most aggressive white cells which fight cancer and all infections. There are about 2100 lymphocytes per micro liter of blood and in general there are about five liters of blood in a normal human body. These lymphocytes circulate in the blood for not more than an hour to look for infections and/or cancer and whenever and wherever they trace any of them they attack vigorously and relentlessly. There are four different kinds of lymphocytes. These are B-cells and three different kind of T-cells. While cytotoxic T - cells directly fight infections and cancer, helper T-cells help them as well as the B-cells to get to the sites of cancer or any

infections. When the fight is over, suppressor T-cells arrive and ingest the dead bacteria and cancer. Thymus is a lymphoid organ located in between the lungs and right on top of the heart. All blood cells originate in the bone marrow. Those which come to the thymus become trained T-cells. After that they take shelter in spleen and mostly in the lymph nodes. Lymph nodes become the castles of the T - cells. Breasts are surrounded by the thymus and chains of lymph nodes. Thus they are well protected organs of the body. Since T-cells can go to every cell to protect it, they definitely go to every cell of the breasts to check the state of their health. Some doctors believe that the thymus does not survive after the age of 45 and then the immune system of the body becomes very weak. Recently, researchers have found that the thymus could stay healthy well beyond the age of 60. Several scientists observed that when a person gets stressed, thymus involutes and the number of T-cells goes down drastically making a person susceptible to infections and cancer. As a person ages, constant exposure to stressful events of life weakens the immune system . Thus some researchers believe that cancer is associated with aging in It has been found that a hormone, called thymosin is secreted by thymus which maintains the lineage of T-cells. Thus artificially thymosin could be injected into the body to help T-cells proliferate even though the thymus is not very active. Researchers at the biomedical center at Lawrence Berkeley Laboratory have found that there exist some chemical therapies which kill more cancer cells and less lymphocytes. Dr.Oppenheimer, from the Cancer Research Institute, at Northridge, California has reported that carcinogens play a very crucial role to cause cancer. Dr.Glenn Webb from Vanderbilt university stated that as cancer strikes, it generates angiogenesis, or vascularization which means each cancer cell tries to draw as much blood as possible to get maximum amount of nutrition. Glucose is a chemical that cancer cells absorb as much as possible. Considering all these factors mathematical modeling was developed to understand how immune system could fight cancer. This model consists of eight nonlinear coupled partial differential equations. Each equation represents the growth and /or decay of a particular organic chemical substance where both cancer cells and lymphocytes are treated like biochemicals. The equations have been derived mathematically applying the law of mass action of Chemistry and the theorems on flux of a chemical as discussed in the Green's theorem. Computationally these equations are moderately stiff and Perturbed Functional Iterations have been used to solve this model. This nonlinear solver does not require any inversion of Jacobians and has a super linear rate of convergence. The results seem to be quite interesting as validated qualitatively by the available data. For instance, if the cancer is detected earlier at any site in the breast, the model predicts that it could be cured. If a person is not stressful, the model predicts that his/her immune system is strong and any growth of cancer could be wiped out by the immune system The model also shows that if cancer has grown reasonably big, regular dosage of chemicals could keep it under control and if has spread too far immune system will very likely fail . The system is still one dimensional. To be more realistic it should be extended to three dimensions so that computational results could be animated properly. Also, since the job of T-helper cells is very special because it does not fight , it only detects cancers, there should be a new equation to represent how it could detect the sites of cancer and/or infections. It has been experienced by many doctors that often cancerous tumors hide their antigens so that T-helper cells may not detect them. At present there is a drug available which could reveal the antigen of any cancer cell. With this idea in view a third equation must also be added in the model showing the interaction between this drug and other chemical injected into the patient's body. Thus will be an ongoing project.

II.E.2.g Charis Kaskiris

'Brahms', an agent-based language – Maarten Sierhuis

As a Visiting Researcher with RIACS/USRA at the NASA Ames Research Center I have been working with Maarten Sierhuis and Bill Clancey on 'Brahms', an agent-based language used to model and simulate human activities. Since June 2001 I have been involved in two projects. The first is an STTR project involved the creation of a Brahms model which would be used as a proof of concept for the integration of Brahms and the OWorlds, a Virtual Reality Environment created by Digitalspace. This project has been completed. The second project is the Mobile Agents Project, where the focus is on designing and simulating the work practice of EVA planetary exploration. As a part of this project, I have been involved in contextual inquiry activities (MEX) and creation of a knowledge base of related information to be implemented in the Brahms model. The project is on-going.

II.E.2.h Dohyung Lee

Multiresolution for Computational Fluid dynamics – Dochan Kwak

Development of data management tools which are essential for the analysis, representation and manipulation of digital data sets such as CFD data, signals from experiments, images and data for virtual flight simulation. The approach is to develop appropriate wavelets suitable for field simulation data and implement computational multiresolution tools (using the newly-developed super compact multi-wavelets) for 3-D numerical simulation data.

A prototype 3-D truncation compression code has been developed and demonstrated using CFD data. This code is based on Beam-Warming's supercompact multiwavelets extended from Harten's interpolatory method.

Detailed accomplishments during this temporary visit are as follows.

- Data compression for overlapping grid solutions:
- Most of full-scale simulations are based on overlapping grid sets. When applying data compression, special care is required for the overlapping region with different grid sets. Some area in one grid set could have garbage values since those area solutions are not necessary.
- A special technique is developed to treat garbage value that could impair the multiresolution process. By relaxation method, those garbage values are replaced with meaningful values
- Relaxation of Power of 2 constraint for multiresolution application:
- Multiresolution application is restricted to the problem size of power of 2 (2,4,8,16,32,64,128...). Therefore, some part of the problem could be excluded. To avoid this, one has to either shrink the problem size or expand the problem to meet the power of 2 requirement. For practical multiresolution application, most area of any problem size must be in possible multiresolution application area. For this objective, various approaches are under consideration. For example, combination of 3D, degenerated 2D and 1D multiresolution method is being tested.

Since most numerical flow solutions are smooth almost everywhere and have discontinuities only in local areas (shock, vortices, and shear layers), it is necessary to use higher-order accurate compact schemes that have least support.

Beam and Warming's supercompact multi-wavelets meet the fundamental requirements in this regard. The algorithm with 3D extension of supercompact wavelets provides efficient CFD data compression. Truncation even with high accuracy (e.g. 1×10^{-6} error) may allow significant compression ratio (around 50:1), thus reducing storage and transmission requirements. Reduced data storage and transmission time will impact HPCC and IPG.

The supercompact multi-wavelets demonstrates great potential in data management technology. The multiresolution with the supercompact wavelets is being tested for data compression on various forms of data sets (simulation and experiments). Particular care is being taken to relax various constraints such as power of 2 problem size constraint.

Wavelet technique will also be utilized for other purposes: feature extraction, pattern recognition, convergence acceleration, grid refinement and adaptation.

II.E.2.i Michael Duke

NASA Human-Enabled Science Program – Lewis Peach

Michael B. Duke contributes to the planning of the science content of future human exploration beyond low Earth orbit and the relationship of human exploration missions to current planning of the robotic exploration of Mars. He organized, planned and conducted a workshop "Science and the Human Exploration of Mars" held at Goddard Space Flight Center in January, 2001. He organized a second meeting and the effort to draft a proposed approach for a NASA Human-Enabled Science Program. He gave presentations on space resource development to the NASA NEXT committee and to the NRC Threads committee evaluating future needs of human exploration technology. He prepared and delivered a paper on future exploration of the Moon for a HEDS-organized session at the AIAA Space-2001 Conference. He served as a representative of HEDS to the Mars Exploration Planning and Analysis Group (MEPAG), contributing to the inclusion of HEDS objectives in the NASA Mars robotic exploration plan.

II.E.2.j David Marshall

Computational Fluid Dynamics – Michael Aftosmis

During my 4 weeks at NASA's Ames Research Center I had the great privilege to collaborate with some of the brightest, knowledgeable and helpful people that I have met. I mainly worked with Mike Aftosmis and Marsha Berger on their computational fluid dynamics (CFD) application CART3D. My main effort was focused on porting CART3D to a distributed memory parallel environment using MPI. I was able to accomplish a significant amount of this effort mainly because the close collaboration and open communication environment that exists in their department allowed me to easily gain the necessary information. While there, I completed approximately 80% of the required work needed to have a working distributed memory parallel version of CART3D. I

also collaborated with Scott Murman on his work extending CART3D to handle unsteady flows and moving boundaries. I also began researching how to handle the extension of CART3D to handle the Navier-Stokes equations with Tom Pulliam and Mike Aftosmis. In all, I found my stay at Ames to be highly rewarding and an incredible educational opportunity that has made a significant impact on my research here at Georgia Tech.

II.E.2.k Brian Murphy

Quantum Computation – Dogan Timuçin, Vadim Smelyanskiy (NASA-Ames), Prof. Yoshihisa Yamamoto, Cyrus Master, Thaddeus Ladd (Stanford)

The idea of quantum computation is that the physical computer obeys the laws of quantum mechanics. This means that bits can be in a superposition of 0 and 1, bits can be entangled to each other, and measurement affects the state of the computer. In 1985, David Deutsch gave an abstract model for quantum computation and raised the question of whether a quantum computer could solve some problems more efficiently than a classical computer. Current areas of research include building a quantum computer, constructing quantum algorithms that are more efficient than the best known classical counterparts, developing error-correction techniques, and investigating the effects of difficulties that will arise in practice such as decoherence, noise, etc.

Summary of results:

At the time that I received a research grant from RIACS (August 2000), I had only just discovered the possibility for a new way to approach database search in quantum computation. My idea was that once you had created a database of all possible solutions to your problem, you could then use phase interference to determine characteristics of the database as a whole. You could then use the information gained from measurement to select a subspace of possible solutions (and reduce the size of the problem).

Operators that create databases and flip phases are already used in other quantum algorithms. The difficult part of this approach is developing a relationship between the measurement of the system and how to use that information. At the end of the summer, while playing with C++ code I wrote to simulate a quantum touring machine, I had just happened upon the possibility for making such a relationship. But at the time I did not know why it existed.

Since then I have made considerable progress:

- Mathematical specification of the exact meaning of all possible measurements of the system (this took several incremental steps)
- Completion of a novel algorithm for solving the set partition problem (with possible extension to general structured database search)
- Creation of tractable simulations of applying my algorithm to the partition problem
- Results showing a potentially advantageous trade-off in performance time versus required number of coherent steps, and use of a quantum heuristic that cannot be mimicked classically
- Preliminary examination of applying this approach to other optimization problems

II.E.2.l Daniel Hammerstrom

Massively parallel VLSI architectures for intelligent systems – Barry Leiner.

The initial project funded by RIACS in 2000 was for the design and simulation of an Associative Data Processor computer architecture. This architecture was based on associative neural network models, and is intended to be an experimental component for a number of applications including image analysis and robotics. The basic architecture was developed, as well as a multiprocessor simulator of the architecture. The simulator has been executed on Lomax, the NAS 512 processor SGI Origin 2000. We were able to simulate networks approaching a million nodes. This work, along with other work at OGI, led to two contracts with the NASA Intelligent Systems program. The two contracts are:

- “Biological computing for robot navigation and control,” NASA IS Program, March 1, 2001, Three years, \$1,393K. PI: Marwan Jabri, Co-PIs: Chris Assad, Dan Hammerstrom, Misha Pavel, Terrence Sejnowski, and Olivier Coenen;
- “Robust Intelligent Systems Based on Information Fusion,” NASA IS Program, March 1, 2001, Three years, \$1,115K, PI: Misha Pavel, Co-PIs: Dan Hammerstrom, Marwan Jabri, Hynek Hermansky, Xubo Song, Al Ahumada, Jeff Mulligan.

Both contracts incorporate investigators from OGI, NASA Ames, JPL, and the Salk Institute. The fundamental computational component in each contract is an associative data processor. Simulations on the large NASA machines are continuing as a part of these programs.

In addition to support from RIACS, the development of the multiprocessor simulator was also funded by the following contract:

- “Simulation and Hardware Analysis of Large Scale Neuronal Models,” Office of Naval Research, Office of Naval Research, October 1, 1999, Two years, \$118,496.

II.E.2.m Mats Larson

A Posteriori Error Estimation for Adaptive Finite Volume Methods – Timothy J. Barth

In many practical situations a numerical computation is performed to obtain a particular value of physical interest, for instance, the lift or drag coefficient of a wing profile. It is therefore important to derive computable a posteriori error estimates, for the error in such desired quantities, and to use those estimates in the design of an adaptive algorithm specifically designed to efficiently approximate one or several such quantities. In recent years the development of such a posteriori error estimates and corresponding adaptive algorithms have been developed for finite element methods, with both continuous and discontinuous approximation. Common to the different approaches is the presence of a continuous dual linearized problem used to connect the error in the desired quantity to a computable estimate of the residual of the computed solution. In practice the dual linearized problem must be solved numerically and an approximate error estimate is calculated. Clearly, the resulting error estimate will not be a rigorous upper bound of the error. In our work we develop a posteriori error estimates for a family of Petrov-Galerkin finite element methods. Where the test space consists of discontinuous piecewise polynomials of degree p and the trial space is a subspace of discontinuous piecewise polynomials of degree q with $q \geq p$.

More precisely, the trial space is obtained by letting a recovery operator act on the trial space. The specific form of the recovery operator is not crucial for the error estimates. The special case of finite volume methods where piecewise constant test functions are used is of particular interest since these methods are popular in commercial applications. We first derive an abstract derivation of estimates for a simple model problem, motivated by fluid mechanics. In particular, we derive a sequence of three different error bounds, obtained by applying analytical inequalities. Next, we approximate the unknown solution to the dual linearized problem by a numerical approximation, and obtain three corresponding error estimates. We evaluate the performance of these estimates numerically for a few simple test cases. We also compare with using the exact solution to the dual linearized problem to study the effect of the use of an approximate dual linearized problem. Note that for a standard finite element method one typically needs to calculate the approximate solution to the dual problem using finer resolution than in for the primal problem due to the orthogonality properties of the method. For a Petrov-Galerkin method the dual problem may be solved using the same resolution as the primal and the error representation formula can be evaluated directly. Our results will be presented in a scientific paper which is in preparation.

II.E.2.n Flavio Lerda

Project: Java PathFinder – Willem Visser

Java PathFinder is a model checking tool that is able to prove properties of Java programs. During FY01 I have been working on the development of the tool and the algorithms it uses to scale to programs of bigger size. The approaches followed to reach this goal include the exploiting symmetries of the system, use of distributed and parallel architectures, compression of the states and partial order reductions. A major redesign of the tool took place during FY01 with the purpose to support all the features in a more rational way and make it more easier to support new ones. Distributed search has been improved by the study and development of dynamic partitioning which have then been applied also to the newly available parallel version of the tool. A paper has been submitted to the 8th International SPIN Workshop, which has been later accepted and was presented in Toronto in May 2001.

II.E.2.o Marian Nemec

Aerodynamic shape optimization problem – Dr. Thomas Pulliam

The goal of this collaboration is to compare genetic and gradient based algorithms for the aerodynamic shape problem. The following tasks were accomplished:

- Comparison of the right hand side of ARC2D with the right hand side of OPTIMA-2D. It is necessary to ensure that the optimization problem is based on the same flowfield equations.
- Implementation of the B-spline airfoil geometry and re-grid procedures from OPTIMA-2D into ARC2D. In order to compare genetic and gradient based algorithms, the underlying design variables and grid modification should be identical.
- Preliminary computational cost comparison between the genetic algorithm and the gradient based algorithm.
- Formulated a set of suitable test cases to compare the two algorithms. The test cases focus on multi-modal objective functions and Pareto fronts.

II.E.2.p David Smith

Improving the Reliability and Predictability of Complex Nonlinear Numerical Simulations – Helen C. Yee

The backward facing step, a classic benchmark problem for the study of separation and transition to turbulence, has recently generated much controversy in the CFD arena. At the core of this lies so called spurious solutions generated by an unfortunate conspiracy between temporal/spatial discretization methods, choice of initial conditions, and/or solution procedure in the time marching context. These nonphysical solutions satisfy the discrete equations but do not represent true solutions of the underlying differential equations. For simple test cases involving ODE's subjected to various discretization procedures and timesteps the possible spurious solution behavior can be demonstrated and analyzed with relative ease to provide a useful insight into the phenomenon. However, for large scale complex nonlinear fluid flow calculations, particularly when the flow physics is not well understood, the presence of spurious solutions is a serious concern and needs urgent attention if reliable CFD codes are to be developed. This study considers the backward facing step and is aimed at understanding the possible spurious solution modes with the ultimate intention of preventing their occurrence in CFD calculations.

Using an existing spectral element CFD code with eighth order polynomial basis functions on a high resolution 138 element grid, steady solutions have been computed by time marching and continued in Reynolds number via zeroth order continuation until the onset of sustained oscillatory behavior between $Re=1750$ and 1800. This demonstrates a known pattern of stability loss as Reynolds number is increased on a given spatial grid and is thought to be the product of a spurious bifurcation inherent to the particular grid, polynomial order, timestep and integration procedure. Additional grid refinement studies are to be carried out in order to examine this dependency.

Zero order continuation has served the purpose of approximately locating the bifurcation, however closer examination is necessary with a more advanced technique capable of accurate location and tracking of spurious branches. For this purpose, RPM continuation, based on splitting the fixed point iteration into slow and fast subspaces and performing hybrid iterations, is also being implemented on the spectral element backward facing step system. Initial success in identifying the slow subspace and hybrid iteration has been achieved, however further development is required to fully utilize the RPM capability.

II.E.2.q Sankaran Venkateswaran

Neural Network Modeling – Meyya Meyyappan

During the current year, Prof. Venkateswaran has worked on neural network modeling of CVD reactors, the application of CVD plasma codes to plasma propulsion applications, and the development of improved algorithms for such applications. The neural network research, performed in collaboration with Drs. M. Rai, T. R. Govindan and M. Meyyappan, involved computing a series of computational fluids dynamic (CFD) computations for training and validating the neural network. The trained network was demonstrated to be capable of representing

both mean and local deposition rates to within one per cent accuracy. The results have been summarized in a forthcoming article in the Journal of the Electrochemical Society. The plasma propulsion research is being performed in collaboration with Dr. D. Bose, T. R. Govindan and M. Meyyappan. It involves modifying existing CFD codes for modeling the electromagnetic acceleration of ionized Xenon gas in a Hall thruster geometry. At the present time, exploratory computations have been carried out and detailed physio-chemical data for Xenon are being incorporated into the code. In addition, progress has been made in the formulation and implementation of improved algorithmic procedures for solving plasma flowfields and are expected to significantly enhance our ability to reliably compute such problems.

II.E.2.r Lofteh Zadeh, Ph.D.

Natural language for information processing – Charles Jorgensen

Significant progress has been made toward an enlargement of the role of natural languages in information processing, decision and control. A methodology for computing with words (CW) has been developed. This methodology serves as a basis for a computational theory of perceptions. A paper entitled “A New Direction in AI -- Toward a Computational Theory of Perceptions” has been published in the Spring 2001 issue of the AI Magazine. Another paper entitled “Toward a Perception-based Theory of Probabilistic Reasoning with Imprecise Probabilities” is scheduled for publication in the Journal of Statistical Planning and Inference.” A book entitled “Computing with Words” was published by Wiley. Computing with words is likely to become a widely used tool for the conception and design of systems which are capable of execution of complex tasks involving recognition, search and automated decision-making. In particular, it could play an important role in the design of unmanned vehicles for exploration of the surface of Mars and other planets.

II.E.2.s David Zingg

Gradient algorithms for optimization – Thomas Pulliam

The collaborative project with Dr. Thomas Pulliam concentrated on the evaluation and characterization of evolutionary and gradient-based algorithms for optimization problems involving expensive objective function evaluations. Specifically, genetic and discrete adjoint methods were compared for two-dimensional aerodynamic design problems based on the numerical solution of the Reynolds-averaged Navier-Stokes equations. This involved the generation of non-inferior sets (Pareto fronts) for competing objective functions. The results provide useful information to guide the application and further development of optimization algorithms, including hybrid methods combining evolutionary and gradient-based algorithms.

II.F Inventions

Based on the work described above as well as work performed in prior years of this cooperative agreement, the following invention disclosure has been filed with NASA.

Case No.	Title	Inventor
ARC-14599-1	Java PathFinder Model Checker	Willem Visser/Klaus Haverlund
TBD	Advanced XML Database Integration	David Maluf

Table 1: Invention Disclosures

III Seminars, Workshops and Technical Reports

RIACS holds both regularly scheduled and special seminars which bring in speakers from the Ames scientific community, university researchers, and high-tech industry researchers. These seminars provide an excellent forum for education and collaboration with leaders in the field.

RIACS also holds and sponsors workshops which address computer science issues in depth by bringing together NASA and RIACS scientists with leading researchers in the field from universities and industry.

III.A RIACS Seminars

Sep. 6, 2001: Phillip C. Dibner, Ecosystem Associates “Spatial Data Sharing and Open GIS Standards”

The ability to share spatially-indexed data has long been sought by governmental agencies, industry, and end users. The petabytes of imagery and other information already online represent an immense resource, much of it in the public trust. As software with spatial components becomes ever more mainstream, the potential for seamless sharing to reduce costs and increase operational capabilities grows accordingly. However, geospatial datasets are often huge, and not easily amenable to wholesale duplication, conversion, or transfer. The solution lies in interoperability via common interfaces that are independent of underlying storage formats, platforms, or management practices. The growing array of standards developed and published by the Open GIS Consortium (OGC), a partnership of more than 200 vendors, agencies, users, and integrators, addresses this need. This presentation will describe the standards themselves, the variety of testbeds, pilot projects, and operational installations in which OGC-conforming products have been used, and plans, hopes, and ideas for distributed spatial databanks in the near future.

Biosketch

Phillip C. Dibner is the principal of Ecosystem Associates, a small consultancy with expertise in software development and environmental analysis. Mr. Dibner’s background combines formal training and professional experience as an ecologist with more than two decades of engineering experience in the software industry, including long stints at Sun Microsystems, NeXT Software, and Apple Computer. He has been involved with the Open GIS Consortium and its predecessors since 1994. He recently founded, and currently chairs, the OGC’s Special Interest Group in Natural Resources and the Environment.

Sep. 6, 2001: Thomas Hester, Bluedot Software “What a J2EE-based Workflow Architecture Can Do for Automated Planning”

There are some striking similarities between workflows and plans. In fact, a workflow application can be considered to be a plan developer and executor. I will formalize the similarities and difference between workflows and plans. Then I will investigate how workflow applications architecture and concepts may be applied to automated planning. Contemporary workflow systems execute plans by executing components that represent plan scenarios. These components are generated directly from UML activity diagrams. The components are implemented as Enterprise

Java Beans and they are implemented in an application-independent form. The components are then translated into multiple application-dependent forms by XSLT. This approach allows substantial plan reuse and it also supports mixed human and machine execution of plans. I will present commercial instances of workflow, including one I implemented, and describe specific applications of a corresponding planning system to some NASA problems.

Biosketch:

Thomas R. Hester has worked as a software and systems architect for 20 years. He built natural language understanding and expert systems at Martin Marietta where he was the Program Manager for NASA projects in the Artificial Intelligence Department. At FMC's AI Center, he built route and tactical planners and was Program Manager for DoD projects at the Center. At the Advanced Decision Systems Division of Booz-Allen Hamilton, he was Director of the Planning Practice and created an object model for a planning component of the Air Force air traffic control system. Subsequently, he was Senior Director of the Distributed Objects Practice at Oracle, Chief Technology Officer for FoundryOne and VP of Engineering at Bluedot Software. At FoundryOne he built a workflow system architecture using J2EE components built using Rational Rose, EJB's, BEA's WebLogic and Oracle8 and stored in a UML activity diagram format in a WebDAV repository. Dr. Hester has a PhD in Computational Linguistics from the University of Texas at Austin.

August 30, 2001: SSRP Participants

Vandi Verma of CMU: "Fault Identification on K9"

Kristin Branson of UCSD: "The Earth-Observing Satellite Domain Model"

Brent Venable of University of Padova: "Learning and reasoning with Temporal Soft Constraints"

Aug. 23, 2001: Dr. Joydeep Ghosh, SAIC

"Graphical Techniques for Efficient and Balanced Clustering of Very High-Dimensional Data"

Segmentation or clustering of large data sets with thousands of dimensions is very challenging because of sparsity problems arising from the "curse of dimensionality". Recent graphical approaches provide novel and efficient solutions by working in similarity space rather than in the original vector space in which the data points were specified. I shall describe one such approach based on constrained, weighted graph-partitioning, that has yielded remarkable results on real-life market basket analysis, clustering web documents and grouping user sessions based on web logs. Issues related to the appropriate choice of similarity space, and how to evaluate and intuitively visualize the clusters will be addressed in the process.

Biosketch:

Joydeep Ghosh is a Full Professor at The university of Texas, Austin, and holder of the Archie Straiton Endowed Fellowship. He directs the Laboratory for Artificial Neural Systems (LANS), where his research group is studying the theory and applications of adaptive pattern recognition, data mining including web mining, and multi-learner systems. Dr. Ghosh has published more than 200 refereed papers and edited 8 books. He has received six best paper awards, including the 1992 Darlington Prize for the Best Journal Paper from IEEE Circuits and Systems Society, and the

Best Applications Paper at ANNIE'97. He was a plenary speaker for ANNIE'97 and letters editor for IEEE Transactions on Neural Networks (1998-2000). He is currently an associate editor of Pattern Recognition, Neural Computing Surveys and Int'l JI. of Smart Engineering Design. Dr. Ghosh served as the general chairman for the SPIE/SPSE Conference on Image Processing Architectures, Santa Clara, Feb. 1990 as Conference Co-Chair of Artificial Neural Networks in Engineering (ANNIE)'93 -ANNIE'96, ANNIE '98-2001, and in the program or organizing committees of several conferences on neural networks and parallel processing. More recently, he co-organized workshops on Web Mining (with SIAM Int'l Conf. on Data Mining, 2001) and on Parallel and Distributed Data Mining (with KDD-2000).

Aug. 23, 2001: Dr. Raj Kumar, The University of Texas, Austin
“Data Mining”

Data Mining is inductive data analysis. When data is too large and complex to be examined by humans, data mining can produce summaries in the form of a ratio or a formula that reveal patterns. Such patterns enable analysts to come to a better understanding of the data. Data mining can be done on a variety of data types, including numerical, text and spatial data. Data mining technologies provide a spectrum of analytical tools such as classification, segmentation and association. However, data mining is still an art: Which analyses to perform in what order is a critical question. The talk introduces several different data mining algorithms and demonstrates how data mining can be used to analyze datasets. As an application of data mining, the talk will discuss about web data mining and the impact of results to a business. At the end, the pitfalls of data mining will be discussed.

Aug. 16, 2001: SSRP Seminars

Jonathan Moody of CMU: “Making HCC Probabilistic (safely)”

Ellen Campana of Univ. of Rochester: “Gaze and Language: Using Eye Movements to Improve Spoken Dialogue System Performance”

Scott Johnson of University of Wyoming: “Lightweight Temporal Logic Runtime Monitoring”

Aug. 9, 2001: SSRP Seminars

Michael Whalen of University of Minnesota: “Software Certification”

Adrian Agogino of University of Texas: “Controlling Collections of Learning Agents”

Kate Mullen of Bard College: “Practical Data Analysis with AutoBayes”

Aug. 9, 2001: Dr. Gregory Aist, Carnegie Mellon University

“Human-computer Spoken Dialog and Intelligent Tutoring Systems”

Human-computer spoken dialog presents the promise of richer interaction with computational systems, as well as access in situations where (for whatever reason) conventional input devices such as mice and keyboards are impractical. Intelligent tutoring systems allow learning to be supported in a computational environment, and to take place where conventional instruction is unavailable. Our long-term goal is to apply human-computer spoken dialog and intelligent tutoring systems to important problems facing society, and furthermore to advance the state of the art in each area. To date we have focused on helping children learn to read. In this talk we will discuss

several challenges we faced and how we addressed them. The skills and methods we employed while working on software for children's literacy (as well as in other endeavors) are, however, broadly relevant to ongoing NASA efforts. Furthermore, NASA domains offer important and challenging problems: problems that are worth addressing in their own right, as well as advancing the state of the art in the underlying technologies.

**Aug. 8, 2001: Dr. Benjamin W. Wah, Department of Electrical and Computer Engineering
University of Illinois, Urbana
"Stochastic Anytime Search Algorithms for Nonlinear Optimization and Planning"**

In this talk, we present a theory and its associated anytime derivative-free search algorithms for solving problems in autonomous control and planning. Planning and scheduling problems can be defined either by a batch formulation in which a planner plans for one horizon based on its current state and goals, or by a continuous formulation in which a planner uses a current goal set, a plan, a current state, and a model of the expected future state to plan for a much shorter planning horizon. In both cases, an instance of a planning problem can be formulated as a constrained mixed-integer nonlinear programming problem (MINLP) whose objective and constraint functions may not be in closed form or differentiable. We first show the transformation of such a constrained MINLP into an unconstrained penalty function and its solution by unconstrained search algorithms. We focus on characterizing constrained local minima (CLM) in the original MINLP by necessary and sufficient conditions on points in the unconstrained penalty function. Given such one-to-one correspondence, the search for points satisfying the necessary and sufficient conditions in the unconstrained penalty function amounts to locating CLM in the original MINLP. Next, we present efficient heuristics and unconstrained stochastic search algorithms in order to look for points satisfying the conditions. Based on these algorithms, we evaluate stochastic anytime search algorithms that generate solutions of improved quality when given more time and computational resources, and that require the minimum average completion time (up to a constant factor) in order to find solutions of prescribed quality. Although such algorithms do not overcome the NP-hardness of large optimization problems, they lead to solutions of improved quality and constraint satisfaction as more time is spent in solving a problem.

**Aug. 3, 2001: Dr. Hans W. Guesgen, University of Auckland, New Zealand
"Solving Fuzzy Constraint Satisfaction Problems"**

Work in the field of artificial over the past twenty years has shown that many problems can be represented as constraint satisfaction problems and efficiently solved by constraint satisfaction algorithms. However, constraint satisfaction in its pure form isn't always suitable for real world problems, as they often tend to be inconsistent, which means the corresponding constraint satisfaction problems don't have solutions. A way to handle inconsistent constraint satisfaction problems is to make them fuzzy. The idea is to associate fuzzy values with the elements of the constraints, and to combine these fuzzy values in a reasonable way, i.e., a way that directly corresponds to the way how crisp constraint problems are handled. The downside of this approach is that solving the problem becomes more complex. Instead of computing any assignment of values to the variables that satisfies the constraints, we are now confronted with the problem of finding an optimal or at least almost optimal assignment. The purpose of this talk is to discuss various techniques for coping with this task.

Aug. 2, 2001: SSRP Student Seminars**Judah Ben DePaula of University of Texas : “Knowledge Base for Data Tracking.”****Alex Groce of Carnegie Mellon: “Heuristic Search for Model Checking Java Programs”****Matthew Deans of Carnegie Mellon: “Beating the Kalman Filter.”****July 26, 2001: Gio Wiederhold, Stanford University****“Improving Precision in Information Systems”**

Precision is important when information is to be supplied for commerce and decision-making. However, a major in the web-enabled world is the load and diversity of information. Through the web we can be faced with more alternatives than can be investigated in depth. The value system itself is changing, whereas traditionally information had value, it is now the attention of the purchaser that has value. New methods and tools are needed to search through the mass of potential information. Traditional information retrieval tools have focused on returning as much possible relevant information, in the process lowering the precision, since much irrelevant material is returned as well. However, for business e-commerce to be effective, one cannot present an excess of data produced. The two types of errors encountered, false positives and false negatives now differ in importance. In most business situations, a modest fraction of missed opportunities (type 1 errors) are acceptable. We will present the tradeoffs and our current direction and tools to enhance precision in information processing to support electronic commerce. <http://www-db.stanford.edu/people/gio.html>

July 25, 2001: Dr. Suhrit Dey, Eastern Illinois University**“Computational Studies of the Immune System of The Body”**

A mathematical model has been developed and solved numerically by perturbed functional iterations. It could predict how cancer strikes the body and how it could grow, especially in the cases of breast cancers. Some reasonable qualitative agreement has been found between mathematical prediction and medical findings

July 12, 2001: Drs. Claude and Helene Kirchner, INRIA, France**“ $2 + 2 = 4$: Shall we prove it?”**

Based on joint works with Gilles Dowek and Thérèse Hardin and the Protheo group in Nancy. “Deduction modulo” is a way to remove computational arguments from proofs by reasoning modulo a congruence on propositions. Such a technique, issued from automated theorem proving, is of much wider interest because it aims at separating deductions and computations. The first contribution of this talk is to provide a “sequent calculus modulo” that gives a clear distinction between the decidable (computation) and the potentially undecidable (deduction). The congruence on propositions can be handled via rewrite rules and equational axioms. Usually rewriting applies only on terms. We show how to allow rewriting atomic propositions into non atomic ones and to give a complete proof search method, called “Extended Narrowing and Resolution” (ENAR), modulo such congruencies. An important application is that this Extended Narrowing and Resolution method subsumes full higher-order resolution when applied to a first-order presentation of higher-order logic. This shows that such a presentation can yield also

efficient proof-search methods. If time permits I will show how these concepts could be naturally implemented in the ELAN framework based on the rewriting calculus.

July 12, 2001: Marjory Johnson, RIACS
“Mobile Networking and NASA”

The objective of the NASA Research and Education Network (NREN) Project is to infuse emerging networking technologies into NASA mission applications. Mobile networking will enable exciting new paradigms for NASA science and engineering, enhancing support for missions that extend into remote areas where it is not economically feasible to create a permanent wired communications infrastructure. NREN recently hosted a workshop at NASA Ames on “Mobile Terrestrial and Space Networking: Supporting the Scientific Community.” The workshop included demonstrations of applications that motivate the need for mobile networking, presentations on satellite communications, wireless networking and sensor networking, and discussions of issues regarding seamless integration. This seminar provides an overview of NREN activities in the area of mobile networking and summarizes the recent workshop demonstrations, presentations, and discussions.

June 21, 2001: Nando de Freitas, UC Berkeley
“Particle Filtering”

Particle filtering (PF) is a sequential Monte Carlo (SMC) method that goes back to the first publicly available paper in the modern field of Monte Carlo simulation (Metropolis and Ulam, 1949). These algorithms allow us carry out on-line estimation of probability distributions when the data arrives sequentially. Recent methodological and computational advances have led to many success stories in tracking, automatic navigation, financial time series, communications and control. In the context of statistical inference and learning, the performance of PF often deteriorates in high-dimensional state spaces. In the past, we have shown that if a model admits partial analytical tractability, it is possible to combine PF with exact algorithms (Kalman filters, HMM filters, junction tree algorithm) to obtain efficient high dimensional filters. In particular, we exploited a marginalization technique known as Rao-Blackwellisation. I will provide and introductory review, discuss Rao-Blackwellisation and some new developments.

June 21, 2001: John Fry, Stanford University
“Adventures in Spoken Dialogue Systems”

Two different spoken dialogue systems are described, a Japanese Language interface to an office robot, and a tutorial dialogue system connected to a Navy shipboard crisis simulator. This trains Navy Captains to do refueling in very rough seas. Some of the lessons learned about system architecture and implementations from these two systems will be presented. Future directions for research will be discussed. Finally how spoken dialogue system can benefit from empirical linguistic research on large spoken corpora of transcribed speech will be outlined.

May 31, 2001: Dimitra Giannakopoulou, RIACS
“Reasoning About Large Systems in a Compositional Way”

Model checking is a highly automated technique for verifying properties of hardware or software systems. When provided with a formal description of a system's behavior and a required property, the model checker exhaustively explores all the states of the system and returns one of the following results: * a yes answer, meaning the property is satisfied by the system; * a counterexample illustrating how the system could violate the property. More often than not, however, the model checker runs out of memory for any system of realistic size. This problem is known as "state explosion", which refers to the exponential relation between the state space of the system and the components of the state. Various techniques have been proposed to address this problem including abstraction, symbolic state representation, and compositionality. Compositionality is recognized as the most promising attack to state explosion. It advocates a "divide-and-conquer" approach to verification, and comes in two forms. "Compositional verification" involves reasoning about properties of a system in terms of properties of its components. Compositional minimization exploits the hierarchical structure of a system to incrementally generate and check its behavior. In this talk, we will discuss these two forms of compositionality, and focus on the main benefits and problems that they introduce. We will demonstrate some initial results on applying such techniques to the Remote Agent, a case study that the ASE group has already analyzed in a non-compositional setting.

May 24, 2001: Joakim Gustafson, Telia Research Stockholm, Sweden
"Multimodal Spoken Dialogue Systems"

Joakim Gustafson, who is visiting Ames from Sweden was formerly at The Royal Institute of Technology (KTH) and is currently employed by Telia Research. This talk will give an overview of several multimodal spoken dialogue systems developed at KTH and Telia Research over the past six years including Waxholm (<http://www.speech.kth.se/waxholm/waxholm2.html>), August (<http://www.speech.kth.se/august/>) and Adapt.

May 23, 2001: Gary Lindstrom & Ganesh Gopalakrishnan, School of Computing, University of Utah
"PV: An On-the-fly LTL-x model-checker combining selective state caching and partial order reductions"
"Platform Independent Thread Externalization In Java"

Partial order reduction requires a proviso to ensure that a process is not continuously enabled in a cycle without being moved in the cycle. We demonstrate that the traditional implementation of the proviso using an in-stack check can lead to un-necessary state explosion. We propose a new partial-order reduction algorithm whose proviso does not use the in-stack check, resulting in a much simpler as well as far more efficient (on our benchmarks) algorithm. Moreover, combining on-the-fly LTL-x model-checking using nested depth-first search and the in-stack proviso is further complicated by the need to communicate extra information between the outer and inner depth-first search phases (as done in SPIN) to avoid soundness problems. All these issues can potentially be further complicated if selective state caching were to be performed. Since our proviso does not depend on the stack, our algorithm can very easily support these combinations. A demo of our model-checker PV based on our algorithm will be presented. [Joint work with Ratan Nalumasu et.al.] Platform Independent Thread Externalization In Java: The Java programming language is designed to make code mobility practical and convenient. However, it does not standardly support

mobility of on-going computations because it lacks the capability to capture, externalize and restore a program's execution state. We present a novel approach to systematically collapse and externalize the execution state of a Java thread. To ensure both compiler and platform independence, the externalization code is introduced into Java class files via post-processing. Our technique involves introducing a new "shutdown" exception class, and wrapping each program phrase that can encounter such an exception with a handler that externalizes the local stack frame, and then re-throws the exception. Overloaded versions of each restartable method are generated which reverse this process and restore each stack frame with appropriately initialized local variables and temporaries, and resume "forward" execution at the appropriate code point. We demonstrate the viability of our approach by describing a prototype implementation using the Voyager distributed object system as a framework, without modification or post-processing of the Voyager run time libraries. Under our extension, threads and agents can execute a "moveTo" operation in any control context without loss of control state. Very favorable performance measures are reported, notably in terms of code size expansion and run time overhead introduced by post processing to support thread migration. [Joint work with Wei Tao]

May 17, 2001: Johann Schumann, RIACS

"AMPHION/NAV: A System for the Deduction-Based Synthesis of State Estimation Software"

All vehicles which are not bound to track or road need a navigation system to determine their exact position and attitude. Modern applications like air traffic or complex space missions have strong requirements with respect to accuracy and reliability of state estimation software. Despite the fact that the mathematical foundation (Kalman filter) has already been developed in 1960, the development of state estimation software is far from trivial and has caused several mission failures (e.g., unit mismatch in Mars Climate Orbiter). In this talk, I present AMPHION/NAV, a prototypical system for the automatic synthesis of state estimation software. This tool which has been developed by the ASE group, takes as input a graphical specification describing the sensors, their geometric relationship, and global requirements (e.g., desired coordinate systems). Then, a logic-based synthesis engine fully automatically generates executable C++ code. The underlying proof calculus and the domain theory guarantees consistency between specification, domain theory, and synthesized code; for example, necessary transformations of coordinate systems are introduced transparently and in a correct way. AMPHION/NAV also generates extensive, hyperlinked documentation for the synthesis task, describing each piece of the software in detail. Thus full traceability between specification and code can be ensured.

May 14, 2001: Oliver Lemon and Stanley Peters, Stanford University Center for the Study of Language and Information

"Modeling Dialogue with Autonomous Systems"

Automatic dialogue systems now provide assistance over the phone in managing contacts, trading stocks, and other moderately scriptable interactions. Current research focuses on richer models of dialogue adequate for conversations whose structure cannot be predicted -- for example, conversations between people and autonomous systems such as artificially intelligent tutors or robotic devices operating in dynamic environments. One of our projects is the development of a multi-modal dialogue system for conversations with an autonomous UAV (a robotic helicopter), as

part of the WITAS project (see links below for details). We take this system as our starting point, and describe our work on modeling dialogue interactions as information-state updates, where complex information states represent a wide context of an ongoing conversation. We are particularly concerned with developing models rich enough to support powerful message generation capabilities. The research also aims at implementing mixed initiatives in conversation, and supporting dialogues about the system's tasks and abilities.

Links:

<http://www-csli.stanford.edu/semlab/witas/demo1/>

<http://www.ida.liu.se/ext/witas/>

May 7, 2001: Martijn Schut, University of Liverpool, UK

“Intention Reconsideration”

Autonomous agents are systems capable of autonomous decision making in real-time environments. Computation is a valuable resource for such decision making, and yet the amount of computation that an autonomous agent may carry out will be limited. It follows that an agent must be equipped with a mechanism that enables it to make the best possible use of the computational resources at its disposal. In so-called Belief-Desire-Intention (BDI) agents, this decision mechanism, known as the reconsideration policy, manages when an agent reconsiders its currently adopted intentions. The BDI agent model recognizes the primacy of beliefs, desires and intentions in rational action, based on the philosophy of practical reasoning. Intentions direct and constrain an agent's planning process and are as such a useful abstraction for controlling the agent's reasoning. Although intentions persist, they are not permanent, and consequently, an agent has to decide on occasion whether to adopt new intentions or to continue to act upon its current intentions. The main focus of our research has been to investigate how an agent reconsiders its intentions efficiently and effectively. In this talk, we present two approaches to constructing intention reconsideration policies that are adaptable with respect to the environment in which the agent operates. These approaches are rooted in traditional decision theory; the first is based on discrete deliberation scheduling and the second on partially observable Markov decision processes. We demonstrate empirically that these novel approaches increase an agent's effectiveness in domains with real world characteristics, i.e., dynamic, unpredictable and inaccessible.

May 4, 2001: David Basin, University of Freiburg

“Deriving and Applying Program Synthesis Calculi”

Over the last decade I have worked with colleagues on several different projects to develop, implement, and automate the use of calculi for program synthesis and transformation. These projects had different motivations and goals and differed too in the kinds of programs synthesized (e.g., functional programs, logic programs, and even circuit descriptions). However, despite their differences they were all based on three simple ideas. First, calculi can be formally derived in a rich enough logic (e.g., higher-order logic). Second, higher-order resolution is the central mechanism used to synthesize programs during proofs of their correctness. And third, synthesis proofs have a predictable form and can be partially or completely automated. In this talk I explain these ideas and illustrate the general methodology employed.

Biosketch:

David Basin leads the Institute for Software Engineering and Programming Languages. He received his bachelors degree in mathematics from Reed College in 1984, his Ph.D. from Cornell University in 1989, and his Habilitation from the University of Saarbruecken in 1996. His appointments include a postdoctoral research position at the University of Edinburgh (1990 - 1991), and afterwards he led a subgroup, within the programming logics research group, at the Max-Planck-Institut fuer Informatik (1992 - 1997). Since 1997 he is a full professor at the University of Freiburg.

May 3, 2001: Amanda Stent, University of Rochester

“Towards More Realistic Natural Language Generation for Spoken Dialogue”

When people talk with computers, they interact very differently from how they interact in conversation with other people. Some of these differences come from people’s adapting to limitations in the computer’s abilities to interact naturally. If we can make computers interact in a more realistic way, we can reduce the cognitive load on users of dialogue systems. In this talk, we pose two questions: * How is language use in human-human spoken dialogue different from other types of language use (e.g. monologue, text, human-computer dialogue)? * How can we build conversational agents capable of producing more human-like dialogue contributions? In answer to these questions, we first outline some differences between language use in human-human conversations and that in human-computer conversations. We then present an architecture that facilitates flexible, human-like natural language generation. We discuss its theoretical underpinnings, and describe how we have implemented it in the TRIPS conversational agent at the University of Rochester (Stent 1999; Allen et. al. 2000; Allen, Ferguson and Stent 2001). We briefly outline how we have incorporated multimodality. Finally, we describe the different types of evaluation we are currently conducting and preparing to conduct.

May 3, 2001: Corina Pasareanu, Kansas State University

“Abstraction and Modular Reasoning for the Verification of Software”

Modern software systems, which are often concurrent and distributed, must be extremely reliable and correct. Finite-state verification (FSV) techniques, such as model checking, are emerging as the front-runner in the race to automate high-quality assurance of software. Such techniques exhaustively check a finite-state model of a system for violations of system requirements stated in a complementary formalism, such as assertions or temporal logic formulas. In the first part of our talk, we will address several of the challenges of building finite-state models of software systems, that are amenable to verification using existing FSV tools. First, the existence of very large or infinite data in software, that comes from (potentially) unbounded data types, makes FSV of software difficult. We consider one method for avoiding this problem: tool support for source-to-source data type abstractions that are used to reduce the data domains of a program to small finite domains. Second, most FSV tools are aimed at reasoning about complete systems, but modern software is, increasingly, built as a collection of independently produced components, which are assembled to achieve a system’s requirements. We will describe an automatic technique for building finite-state models of software components that enable modular reasoning, taking into account assumptions about the behavior of the environment in which the components will execute. We will illustrate the application of our approach to FSV of software on a large case study, written in Java. In the second part of the talk, we will describe several possible extensions of our

current research work. In general, the abstractions that we studied, are used for checking universal properties (i.e. properties that hold along every possible execution path). We will show how one technique that we developed for the analysis of counter-examples produced by checks of abstracted programs can be customized to enable verification of existential properties (i.e. properties that hold along some possible execution path). We will also show how to extend the abstraction technique (that handles base types) to more general data structures, using abstractions similar to the ones from shape analysis. An example of heap abstraction is the canonical abstraction of a Java object, induced by the abstract values of non-static fields (the abstraction maps all concrete instances of some Java class that have the same abstract values for all non-static fields, to the same abstract instance).

May 3, 2001: Dr. Stacy Marsella, Information Sciences Institute
“Experiences acquired in the design of RoboCup teams”

Increasingly, multi-agent systems are being designed for a variety of complex, dynamic domains. Effective agent interactions in such domains raise some of the most fundamental research challenges for agent-based systems, in teamwork, multi-agent learning and agent modeling. The RoboCup initiative was initiated to foster research in multi-agent systems. It is simultaneously both a research effort and a set of competitions based on the domain of soccer. Since its inception, it has blossomed into a significant international effort which now includes research on multi-agent modeling in disaster rescue. In this talk, I will discuss the research we have done in the RoboCup simulation league and the general lessons we have extracted from participation in RoboCup competitions. We have fielded two teams and have also used the competitions as a source of data for developing team analysis tools. I will also cover recent efforts in the disaster rescue domain.

Apr. 5, 2001: Dr. John Toole, Computer Museum History Center - NASA Ames
“Challenges of Preserving Computing History: The Computer Museum History Center at Moffett Field”

As a partner in the proposed NASA Research Park, the Computer Museum History Center brings a rich heritage and exciting future to Moffett Field. As an independent non-profit organization, it is dedicated to preserving for posterity the artifacts and stories of the information age. It currently boasts a diverse and internationally respected collection of over 3,000 artifacts, 2,000 films and videotapes, 5,000 photographs, 2,000 linear feet of documentation, and gigabytes of historical software – housed temporarily in two warehouses in front of Hangar 1. Although everyone recognizes how rapidly the information revolution has been changing our lives over the last 50 years, most are unaware that the history of the Information Age is being lost! When the world looks back 500 years in the future, we will owe it to ourselves and our descendants to tell the story how these 50 years have made such a difference. The seminar will discuss the background of the Computer Museum History Center; some of our artifacts and why they are important; and discuss some of the interesting challenges of presenting history. How might we present software in exciting ways? How can we address different technical and educational audiences? How can we learn from the past? How can we “capture” history? How can we use the dynamics of research and our industry to help create new solutions? These are other provocative questions will be discussed in the context of being operational in a new world-class facility in 2005.

Biosketch:

As the Executive Director and CEO of The Computer Museum History Center, John C. Toole oversees and drives the overall strategic vision of the museum, and reports directly to the Board of Trustees. In this position, Toole leverages more than 28 years of research and development experience in advanced computing, networking, information technology and microelectronics, culminating in national leadership positions in science and technology management across industry, academia, and government. Formerly one of two deputy directors at the National Center for Supercomputing Applications (NCSA) at the University of Illinois, Urbana Champaign, Toole oversaw the technical operation and coordination of the National Computational Science Alliance. Prior to the NCSA, Toole was the first fulltime director of the National Coordination Office (NCO) for Computing, Information, and Communications, working for the White House Office of Science and Technology Policy. He also served as executive director for High Performance Computing and Communications for the Defense Advanced Research Projects Agency (DARPA), and as acting director – after several years as program manager and deputy office director – of DARPA’s Computing Systems Technology Office (CSTO), which was responsible for advancing computing systems technologies. Toole retired from the U.S. Air Force in 1994 after more than 22 years of service. He holds BS and MSEE degrees from Cornell University. www.computerhistory.org

Apr. 5, 2001: Dr. Lisa Faithorn, RIACS**“The NASA Astrobiology Institute: An Experiment in establishing a ‘Virtual Community’”**

A key objective for NASA’s investment in the NASA Astrobiology Institute (NAI) is the support of innovative collaborative research in the emerging arena of astrobiology, involving scientists from multiple disciplines and different institutions. The catalyzing of collaborative research among distributed groups requires that opportunities be provided for face to face and virtual interaction among scientists who have not historically sought to work together. It also requires active exploration of, and attention to, the behaviors and preferences associated with new forms of productive cooperation. NAI was thus established not only to fund scientific research on existing astrobiological topics but also to catalyze new possibilities for scientific collaboration through the activities it promotes among its Members. NAI was conceived from the beginning as a “virtual institute” in which a variety of communication and collaboration tools, technologies and processes was to be made available to the geographically dispersed Members in order to facilitate productive engagement. The NAI “experiment” is now in the third year of its initial five year cycle. There are substantial lessons learned as well as challenges to be addressed regarding what it takes to promote scientific collaboration in astrobiology and develop the technological infrastructure necessary to support an active and successful virtual community of scientific colleagues. This seminar will provide a brief over view of NAI and focus on some of the lessons learned and current challenges now faced, particularly with regard to communications and collaboration technologies and techniques

Biosketch:

In her role as NAI Collaborative Research Manager over the last 6 months, Dr. Lisa Faithorn has been involved in the efforts of NAI to further the collaboration functions of the Institute and to critically assess and further develop its technological infrastructure. She brings to this role long-

term experience in scientific field research and academic teaching as well as expertise in organizational development and collaborative group facilitation. She also incorporates into her work large-scale organizational and project evaluation efforts. Formerly, she co-founded, and, for fourteen years, directed and taught in the graduate program at the California Institute of Integral Studies in San Francisco. Lisa has conducted field research in Papua New Guinea and northern India, as well as organizational culture studies within the U.S.

Mar. 22, 2001: Dr. Eugene Miya, NASA Ames
“Digital Libraries = succ(succ(ARPAnet))”

Starting in 1994, three agencies of the Federal Government (NSF designated as lead, DARPA, and NASA) sought funding for the “next great thing.” This was basic, fundamental research. Digital Libraries Initiative, Phase 1 was a four year (FY95-FY98), six university effort with fairly homogeneous funding. Digital Libraries Initiative, Phase 2 is a five year mix of small and medium-sized projects some with Internationally funded partners. Half a dozen new Federal funding partners have also hopped on board. The Initiative is now too large to survey all projects. This presentation will be an overview of how-to best determine mutual interests. We will cover who the players are, who’s not playing, and a few highlights about what is happening (locally: 3 projects at Stanford, 2 Berkeley projects [soon 3], and projects at UCD and UCSB). Some project investigators will likely be visiting Ames in the near future. While the results of DLI-1 and DLI-2 are regard as a long term benefit, if you use the Google search engine, this was developed under DLI-1. Other things to look for will be new experimental network protocols for search engine query, geographic information systems (GIS), new concepts for old documents, biomedical informatics, turning a video stream into a direct access medium, and more.

Mar. 21, 2001: Dr. John McCarthy, Stanford
“Approximate Objects and Approximate Theories”

We propose to extend the ontology of logical AI to include approximate objects, approximate predicates and approximate theories. Besides the ontology we treat the relations among different approximate theories of the same phenomena. Approximate predicates can’t have complete if-and-only-if definitions and usually don’t even have definite extensions. Some approximate concepts can be refined by learning more and some by defining more and some by both, but it isn’t possible in general to make them well-defined. Approximate concepts are essential for representing common sense knowledge and doing common sense reasoning. Assertions involving approximate concepts can be represented in mathematical logic. A sentence involving an approximate concept may have a definite truth value even if the concept is ill-defined. It is definite that Mount Everest was climbed in 1953 even though exactly what rock and ice is included in that mountain is ill-defined. Likewise, it harms a mosquito to be swatted, although we haven’t a sharp notion of what it means to harm a mosquito. The talk treats successively approximate objects, approximate theories, and formalisms for describing how one object or theory approximates another.

Mar. 16, 2001: Dr. Yolanda Gil, USC/ISI
“Acquiring Knowledge from Users: Results and Challenges”

Allowing users to update and extend the knowledge in an intelligent system remains a largely unresolved research challenge. I will motivate this need based on practical experiences in several planning task domains. I will review briefly the state of the art in knowledge acquisition research to introduce our approach within the EXPECT project at USC/ISI. EXPECT derives a model of the interdependencies between individual pieces of knowledge and analyzes them to understand how new knowledge added by a user fits in and what additional knowledge needs to be acquired. EXPECT's knowledge bases include ontologies and declarative descriptions of problem solving knowledge. EXPECT's representations include declarative descriptions of problem solving knowledge and are closely integrated with LOOM, a knowledge representation system based on description logic. We have developed several effective techniques that include structuring acquisition dialogues with users through scripts, detecting and resolving errors in a knowledge base through interdependency analysis, and interacting with users in English through structured editors. I will describe briefly several large knowledge bases for planning that we have developed over the last decade and that have enabled us to ground our ideas in practical problems, including a workarounds planning aid that showed the best performance at a DARPA High Performance Knowledge Bases Battlespace Challenge Problem. Finally, I will show results from several user evaluations that we have conducted to test some aspects of EXPECT and that illustrate some of the challenges ahead.

Biosketch:

Yolanda Gil is a Senior Research Scientist and Project Leader at USC's Information Sciences Institute and a Research Assistant Professor in the Computer Science Department. She is principal investigator of the EXPECT project, with a research focus on developing of knowledge-based systems with large amounts of background knowledge and on modeling and reusing of problem-solving methods to guide knowledge acquisition. Her current research interests include knowledge acquisition, knowledge-based systems, planning, and the semantic web. She received her Ph.D. in Computer Science from Carnegie Mellon University, and her undergraduate degree from the Polytechnic University of Madrid. She recently received a Best Paper Award at the 2001 conference on Intelligent User Interfaces (IUI), and is co-chair of the new conference on Knowledge Capture (K-CAP). More information can be found at <http://www.isi.edu/~gil>.

Mar. 8, 2001: Charles Perkins, Nokia

“Mobile Information Systems - Mobile IP”

Mobile IP is under serious consideration in various working groups as a protocol component for a new cellular infrastructure. Groups within the IETF, 3GPP, and 3GPP2 all have related but distinctive perspectives on how to realize the still-nascent potential offered by Mobile IP. In this talk, I will describe some of these recent developments, concentrating on Mobile IPv6 and AAA (Authentication, Authorization, and Accounting). AAA is receiving a lot of attention related to Mobile IP and mobile networking, because service providers need authorization before they can establish a business relationship with mobile computer users that may roam into their area of service. This attention to the profit-making possibilities for mobile networking seems likely to provide a big boost for the deployment of Mobile IP. In this way, AAA will also provide additional impetus for creation of the wireless Internet. All major cellular standardization bodies are making Mobile IP and AAA services an integral part of the new cellular infrastructure. There is also a recognition that IPv6 is crucial for the eventual deployment of billions of IP-addressable

wireless devices. I will end this talk by taking a look at the interactions between Mobile IPv6 and AAA, pointing out new areas needing work and making some guesses about the directions that may be taken within the IETF.

Biosketch:

Charles E. Perkins is a Research Fellow at Nokia Research Center, investigating mobile wireless networking and dynamic configuration protocols. He is the editor for several ACM and IEEE journals for areas related to wireless networking. He is serving as document editor for the mobile-IP working group of the Internet Engineering Task Force (IETF), and is author or co-author of standards-track documents in the mobileip, manet, IPv6, and dhc (Dynamic Host Configuration) working groups. Charles has served on the Internet Architecture Board (IAB) of the IETF and on various committees for the National Research Council. He is also associate editor for Mobile Communications and Computing Review, the official publication of ACM SIGMOBILE, and is on the editorial staff for IEEE Internet Computing magazine. Charles has authored and edited books on Mobile IP and Ad Hoc Networking, and has published a number of papers and award winning articles in the areas of mobile networking, ad-hoc networking, route optimization for mobile networking, resource discovery, and automatic configuration for mobile computers. See <http://people.nokia.net/~charliep> for further details.

March 2, 2001: Dr. Maja Mataric , Univ. of Southern California

“Efficient Control and Learning in Complex Robotic Systems: Robot Teams and Humanoids on Their Best Behavior”

Behavior-based control, which exploits the dynamics of collections of concurrent, interacting processes coupled to the external world, is both biologically relevant and effective for problems featuring local information, uncertainty, and non-stationarity. We have developed efficient methods for principled behavior-based control and learning in two problem domains: multi-robot coordination and humanoid imitation. In this talk, we focus on the first domain, and touch briefly on the second. In the multi-robot domain the key challenges involve reconciling individual and group-level goals and achieving scalable, on-line real-time learning. How to do all of this in a distributed behavior-based way in a timely and consistent fashion? We describe our results in making distributed, behavior-based systems perform in a well-behaved fashion on problems of behavior selection at the individual and group level, communication for dynamic task allocation, and on-line model learning. We describe the use of Pareto-optimality and satisficing to make behavior selection both principled and timely, the robust publish/subscribe messaging paradigm for distributed communication, and augmented Markov models for on-line real-time model building for adaptation. We demonstrate the results of these methods on groups of locally-controlled but globally efficient cooperative mobile robots performing distributed collection, multiple-target-tracking and capture, and coordinated object manipulation. At the end of the talk we touch on the humanoid control domain, where the key challenges are the high dimensionality of the problem and the choice of representation and modularity that properly integrates the perceptual and motor systems. We describe an imitation learning system that employs direct sensory-motor mappings within the behavior-based framework to address how to understand, segment, and map the observed movement onto the existing motor system. The same structure serves for recognition, classification, prediction, and learning. We demonstrate the results on a 20 degree-of-freedom dynamic humanoid imitating human dance and sports movements from visual data.

Biosketch:

Maja Mataric is an assistant professor in the Computer Science Department and the Neuroscience Program at the University of Southern California and the Director of USC Robotics Research Labs. She joined USC in September 1997, after two and a half years as an assistant professor in the Computer Science Department and the Volen Center for Complex Systems at Brandeis University. She received her PhD in Computer Science and Artificial Intelligence from MIT in 1994, her MS in Computer Science from MIT in 1990, and her BS in Computer Science from the University of Kansas in 1987. She is a recipient of the NSF Career Award, the IEEE Early Career Award, and the MIT TR100 Innovation Award. She has worked at NASA's Jet Propulsion Lab, the Free University of Brussels AI Lab, LEGO Cambridge Research Labs, GTE Research Labs, the Swedish Institute of Computer Science, and ATR Human Information Processing Labs. Her research is in the areas of control and learning in behavior-based multi-robot systems and skill learning by imitation based on sensory-motor primitives.

<http://robotics.usc.edu/~maja>

**Feb. 26, 2001: Dr. Ron Larsen , Maryland Applied Information Technology Initiative
“Dynamic Control of Emergent Behavior in E-Commerce Ecologies”**

Information Dynamics is an information-centric approach to system design and analysis. While in its early stages of development, it starts from the observation that advances in computing and communications hardware technology are not being matched by advances in design, analysis, implementation, operation, maintenance and support. This creates an imbalance that currently is reflected in softening sales of new equipment and difficulty in designing increasingly complex systems. Information Dynamics seeks an alternative paradigm to the traditional process-centric view of system design. Information Dynamics explicitly considers the role information plays in a system and, thereby, takes into account what information is needed, when it is required, where it is located, and how it contributes to the operation of the system. Information is treated as a dynamic entity; dynamics (e.g., location, timeliness, value) are explicitly considered. Transformation of information consumes resources (e.g., time, memory, bandwidth). System operation, likewise, consumes resources and feeds back on the dynamics of the information upon which it depends. Information value, or utility, is necessarily associated with a context; utility typically changes with time within a given context, and may be instantaneously different across contexts. In this seminar, the Information Dynamics framework will be described and illustrated using an agent-based electronic commerce scenario. Ultimately, the intent is to be able to model, understand, and control emergent behavior arising from the interaction of many agents in a networked environment.

Biosketch:

Dr. Larsen is currently the Executive Director of the Maryland Applied Information Technology Initiative (MAITI), a consortium of eight Maryland universities committed to doubling their graduates in information technology by 2004. He is also an affiliate associate professor in the Computer Science Department and a researcher on topics related to digital libraries and networked information systems. Between 1996 and 1999, Dr. Larsen was the Assistant Director of the Information Technology Office (ITO) at the Defense Advanced Research Projects Agency (DARPA), where he developed and managed the Information Management program and the Translingual Information Detection, Extraction, and Summarization (TIDES) program. He was also

responsible for DARPA's involvement in the multi-agency Digital Library Initiatives. Prior to his tenure at DARPA, Dr. Larsen was the Associate Director of the University of Maryland Libraries, where he led the implementation and deployment of a State-wide library automation system supporting the eleven campuses and two laboratories of the University. From 1968 to 1985, he was a computer scientist at NASA, developing real time mission support systems, conducting research in computer networking, and developing an agency-wide research program in computer science and automation.

Feb. 22, 2001: Willem Visser, Charles Pecheur, RIACS

“Verification and Validation of Autonomous and Adaptive Systems”

This talk will summarize discussions that took place during the RIACS Workshop on the Verification and Validation of Autonomous and Adaptive Systems (Asilomar Conference Center, Pacific Grove, CA, 5-7 Dec 2000). Discussions include: V&V of Intelligent Systems: How to verify and validate systems featuring some form of AI-based technique, such as model-based, rule-based or knowledge-based systems. V&V of Adaptive Systems: How to verify and validate systems featuring adaptive behavior, either in the form of parametric adaptation (e.g. neural nets, reinforcement learning) or control adaptation (e.g. genetic programming). V&V of Complex Systems: How to verify and validate systems with different interacting parts, either within a given location (e.g. layered control architectures) and among several locations (homogenous or heterogeneous multi-agent systems). See <http://ase.arc.nasa.gov/vv2000/asilomar-report.html> for more details.

Feb. 8, 2001: Robert Morris , RIACS

“Issues in Planning and Scheduling of Earth Observing Satellites”

NASA's growing fleet of Earth-observing satellites employ advanced sensing technology to assist scientists in the fields of meteorology, oceanography, biology, and atmospheric science to better understand how the Earth's systems of air, land, water and life interact with each other. Each satellite's limited resources of power, memory, and sensing instrumentation, as well as ground stations for communicating data and telemetry commands, must be efficiently allocated for the purpose of acquiring, storing, and downlinking high quality images of the earth. With fleets of satellites, there is the added requirement of planning for the coordination of satellites to achieve scientific or operational goals. This talk will be an overview of the challenges faced by both current and future EOS mission operations planners in order to ensure that mission objectives are achieved. This talk will also describe a current effort by the Planning and Scheduling group at Ames to develop an automated system for planning and scheduling earth observations. Among the specific topics covered in this talk are the following:

- A characterization of the planning problem for EOS operations, including both long term planning and daily scheduling of scientific and operational activities.
- A description of the current mission operations planning and scheduling process, as exemplified by Landsat 7 mission operations.
- A survey of current approaches to automated planning and scheduling in the EOS domain.
- A glimpse into the future of EOS missions, which will involve confederations or constellations of spacecraft employing a collection of sensing instruments with different resolution capabilities and, possibly, more powerful on-board processing.

Jan. 25, 2001: Douglas R. Smith, Kestrel Institute
“Mechanizing Software Development by Refinement”

This talk presents a mechanizable framework for software development by refinement. The framework is based on a category of specifications. One of the key ideas of Designware is representing knowledge about programming concepts, such as algorithm design and datatype refinement, by means of taxonomies of design theories. The framework is partially implemented in the research systems Specware, Designware, and Planware. Specware provides basic support for composing specifications and refinements, and generating code. Specware is intended to be general-purpose and has found use in industrial settings. Designware extends Specware with taxonomies of software design theories and support for constructing refinements from them. Planware builds on Designware to provide highly automated support for requirements acquisition and synthesis of high-performance scheduling algorithms.

Jan. 24, 2001: Manfred Broy, Institut für Informatik, Technische Universität München
“A Logical Basis for Component-Based Systems Engineering”

In a systematic development of distributed interactive software systems we work with a basic system model and description techniques providing specific views and abstractions of systems such as the interface view, the distribution view, and the state transition view. Each of these views is helpful and has its place in the systems development process. We show how to formalize these views by mathematical and logical means. The development of systems consists in working out these views that lead step by step to an implementation, which in our approach is given by a set of distributed, concurrent, interacting state machines. For large systems, the development is carried through several levels of abstraction. We demonstrate how to formalize the typical steps of the development process and how to express and justify them directly in logic. In particular, we treat three steps of development by refinement: refinement within one level of abstraction, transition from one level of abstraction to the other, implementation by glass box refinement. We introduce refinement relations to capture these three dimensions of the development space. We derive verification rules for the refinement steps. This way, a comprehensive logical basis for the development of systems is provided.

This work was carried out within the Forschungsverbund ForSoft, sponsored by the Bayerische Forschungsförderung, and the project SysLab sponsored by Siemens-Nixdorf and partially supported by the Deutsche Forschungsgemeinschaft under the Leibniz program.

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Jan. 12, 2001: James Ostrowski, General Robotics, Automation, Sensing, and Perception
(GRASP) Laboratory, University of Pennsylvania
“Robotic Walking, Swimming, and Flying: Combining Sensing and Control in Dynamic Robotic Locomotion”

In this talk, I will describe a hierarchical framework that we are currently developing for the control and motion planning of a class of dynamic robotic locomotion systems. We study systems whose dynamics possess rotational and translational symmetries, as are found in neutrally buoyant motions of spatial rigid bodies. This work builds upon previous research in nonholonomic systems

and geometric mechanics that has led to a single, simplified framework that describes this class of systems, which includes examples such as wheeled mobile robots; undulatory robotic and biological locomotion systems, such as snakes, eels, and paramecia; and the reorientation of satellites and underwater vehicles with attached robotic arms. I will describe our current and previous work on vision-based control of an autonomous blimp-like vehicle, where visual servoing techniques have been developed that combine sensing with the underlying dynamics of the system. This includes more recent extensions for controlling such underactuated systems and dealing with external drift fields such as air currents. I will also highlight current research into vision-based tracking of targets and formation keeping for legged and wheeled robots, as well as closed-loop motion planning using visual feedback for a swimming, eel-like robot. <http://www.cis.upenn.edu/~jpo/home.html>

Jan. 11, 2001: Stewart H. Sonnenfeldt, Vice President of Corporate Development, WebEx Communications, Inc.

“Dial Tone for Web Meetings - What does it take?”

With the explosive growth of the Internet as the critical medium for the global exchange of knowledge and business activity, today's extended enterprises of customers, suppliers, partners and employees are becoming larger, increasingly complex, and more widely dispersed. The benefit of conducting real-time professional/business communication and collaboration over the web has become a tremendous competitive advantage for enterprises and knowledge professionals. Today's enterprises, however, require a comprehensive network services and applications platform that enables flexible and spontaneous sharing of content and applications along with integrated audio and video conferencing. WebEx has built a unique communications infrastructure based on the T.120 standard. This technology is analogous to telephone switching systems and enables true real-time interactive communication sessions that combine voice, data and video. This platform offers deep communication functionality, solid reliability and massive scalability. The talk will give an overview of the challenges and solutions involved in delivering dial-tone for web meetings.

December 7, 2000: Marie desJardins, SRI International

“Towards Formal Methods for Rational Agents”

Using inductive machine learning techniques to construct classification models from large, high-dimensional data sets is a useful way to make predictions in complex domains. However, these models can be difficult for users to understand. In this joint work with Penny Rheingans (University of Maryland, Baltimore County), we have developed visualization methods that help users to understand and analyze the behavior of a learned model, including techniques for high-dimensional data space projection, display of probabilistic predictions, instance mapping, variable/class correlation, and analysis of display space variability. In the talk, I will illustrate these techniques in a census domain, and show how they can be used to give further insights beyond the summaries of model behavior that are provided by commonly used statistical tools.

Biosketch:

Marie desJardins is a senior computer scientist at SRI International. Her ongoing research projects are developing methods for multi-agent planning and negotiation and mixed-initiative planning and

knowledge acquisition techniques. Other research interests include probabilistic reasoning, decision theory, and knowledge representation. Dr. desJardins was awarded a Ph.D. in artificial intelligence from the University of California at Berkeley in 1992, where her dissertation presented a model for autonomous machine learning in probabilistic domains. She received her A.B. in engineering / computer science from Harvard University in 1985

December 4, 2000: Michael Fisher, Department of Computer Science, University of Liverpool, Liverpool L69 7ZF, UK
“Visualization Techniques for Understanding and Analyzing Learned Models”

Agent-Based systems are beginning to be used in a significant number of areas, and are suggested as providing appropriate solutions for an even wider range of problems. Although there is still considerable debate concerning the detail of what exactly should constitute an agent, there is general agreement that an agent-based approach often provides an appropriate abstraction for modeling and implementing complex systems. The type of agents that we are concerned with here are typically termed ‘rational’ or ‘intelligent’. Such agents can be characterized as autonomous components, having their own goals and beliefs and being able to reason about their present and future behavior. Although not widespread in the software industry, such agents are likely to be used increasingly often, especially as more complex domains are considered.

In this talk, I will introduce a logical framework (based on combinations of modal and temporal logics) in which simple rational agents can be described, and will then consider the two questions: 1. how can we reason about agents described using this theory; and 2. how can we implement agents that actually correspond to such logical descriptions? First, I will show how resolution-based proof approaches can be used in order to mechanize these complex logical theories. Next, I will outline our work on implementing rational agents by directly executing their logical specifications. Finally, I will briefly mention our ongoing/future work on proof and implementation methods for rational agents.

December 4, 2000: Peter Engrand (NASA KSC)
“Model Checking of Autonomy Models for a Mars In-Situ Propellant Production Facility”

This is a preview of a presentation to be given at the RIACS Workshop on V&V of Autonomous and Adaptive Systems on Wednesday. The talk relates the ongoing efforts at KSC in using the SMV model checker to support the development of an autonomous controller based on the Livingstone system for the Mars-bound ISPP facility. It gives concrete examples of the kind of errors that have been addressed using V&V, and illustrates the difficulties met by a developer not acquainted with formal methods when trying to use those tools on real problems. The ISPP (In-Situ Propellant Production facility) is designed to produce spacecraft propellant out of the CO₂ in Mars atmosphere. Livingstone is a model-based diagnosis system developed by the Autonomy group here at Ames. SMV is a symbolic model checker from Carnegie Mellon University. A translator from Livingstone models into SMV models has been developed by the ASE group here at Ames, in partnership with CMU.

November 30, 2000: Zara Mirmalek , RIACS
“Inside a Minute and a Half: Participant Observation in Work Systems Design”

1.5 minutes is an observed length of time for the transaction that takes place between an employee and a customer at United Airlines. An examination of the technology and human factors that are brought together for these moments to occur are looked at using the multiple perspectives available in the method of participant-observation. In an ethnography of customer service representatives and customers at United Airlines data was collected for considerations of changes to design of the work system in the areas of training and application.

November 9, 2000: Larry Pyeatt, Ph.D., Texas Tech University
“Learning Low Level Actions for Robot Navigation”

This seminar presents an architecture for mobile robot navigation in which low level actions are learned on-line as the robot performs its tasks. The actions are adaptive to failures in sensors and effectors, allowing the robot to perform its assigned tasks despite hardware failure. Reactivity, deliberation, and learning are an integral part of the architecture. The architecture uses a partially observable Markov decision process (POMDP) approach for path planning, and reinforcement learning (RL) for low level actions. The initial implementation of this architecture has been validated using simulation. The experiments conducted using simulation indicate that the combination of POMDP planning and reinforcement learning provides a very reactive system that can also achieve long term goals, adapt to failures, and learn new low level actions. Work is currently in progress to port the architecture to run on a mobile robot.

November 9, 2000: Daniel E. Cooke, Ph.D. NASA Ames Research Center and Texas Tech University
“Automatic Parallel Control Structures in SequenceL”

SequenceL is a language that provides declarative constructs for nonscalar processing. Rather than specifying program control structures that, in turn, imply a data product, the problem solver specifies a data product and the control structures to produce or process the data product are implied. Although SequenceL has been previously introduced in two papers, recent improvements to the language have indicated that parallel control structures are also implied by the SequenceL problem solutions. This presentation focuses on these recent advances. The talk will be an overview of the execution of SequenceL functions for Matrix Multiply, Gaussian Elimination, and Quicksort - and compare the SequenceL solutions with solutions provided in multithreaded JAVA and C/MPI codes. We are confident that the current research results will allow one to find the inherent (or natural) parallelisms that exist in a given problem solution. The examples reviewed in this talk indicate SequenceL's adeptness in handling a good range of parallel problems. The matrix multiply is an example where there are no dependencies among the computations taking place in the parallel paths. The Gaussian Elimination code is one where there are dependencies among the parallel computations. In terms of scheduling, both the matrix multiply and the Gaussian Codes are examples of problems for which static a-priori schedules can be generated. The paths of execution can be determined based upon the dimensions of the matrix, in the matrix multiply, and the number of equations, in the Gaussian code. The final example, the Quicksort, provides insight into problems requiring dynamic scheduling - the number and schedule for the parallel paths occurs on the fly, regardless of the method used to choose the pivot. The talk will then move towards the facility SequenceL provides in new exploration paradigms. In these new paradigms, processes

seek out data rather than having data presented to processes in a traditional input mechanism. Furthermore, processes share state information so that they can pass around partial computations.

October 30, 2000: Eugene Eberbach, Professor, Principal Scientist, Jodrey School of Computer Science Acadia University, Canada
“Bounded Rationality, \$-Calculus and Power Grid”

Abstract: Recently, there has been shift from consideration of optimal decisions in games to a consideration of optimal decision-making programs for dynamic, inaccessible, complex environments such as the real world. Perfect rationality is impossible in these environments, because of prohibiting deliberation complexity. Anytime algorithms attempt to trade off result quality for the time or memory needed to generate results. Bounded rational agents are ones that always take the actions that are expected to optimize their performance measure, given the percept sequence they have seen so far and limited resources they have. Process algebras, with basic programming operators, has been used to study the behaviors of interactive multi-agent systems and leading to more expressive models than Turing Machines, e.g., Interaction Machines. By extending process algebra operators with von Neumann/Morgenstern's costs/utilities, anytime algorithms can be viewed as a basis for a general theory of computation. As the result we shift a computational paradigm from the design of agents achieving one-time goals, to the agents who persistently attempt to optimize their happiness. We call this approach \$-calculus (pronounced “cost-calculus”), which is a higher-order polyadic process algebra with a utility (cost) allowing to capture bounded optimization and metareasoning in distributed interactive AI systems. \$-calculus extends performance measures beyond time to include answer quality and uncertainty, using k Omega-optimization to deal with spatial and temporal constraints in a flexible way. This is a very general model, just as neural networks or genetic algorithms, leading to a new programming paradigm (cost languages) and a new class of computer architectures (cost-driven computers). The NSERC supported project on \$-calculus aims at investigation, design and implementation of a wide class of adaptive real-time distributed complex systems exhibiting meta-computation and optimization. It has also been applied to the Office of Naval Research SAMON robotics testbed to derive GBML (Generic Behavior Message-passing Language) for behavior planning, control and communication of heterogeneous Autonomous Underwater Vehicles (AUVs). Some preliminary ideas have also been utilized in the 5th Generation ESPRIT SPAN project on integration of object-oriented, logic, procedural and functional styles of programming in parallel architectures. It appears that \$-calculus can be useful for the NASA Information Power Grid (IPG) Project. The IPG testbed provides access to a widely distributed network of high performance computers. \$-calculus resource-bounded optimization allows for flexible allocation of resources and scalability needed to tackle hard computation problems, thus \$-calculus could provide a unifying metasystem framework for the Information Power Grid.

Biosketch:

Dr. Eberbach is a Professor at School of Computer Science, Acadia University and an Adjunct Professor at Faculty of Graduate Studies, Dalhousie University, Canada. Previously he was Senior Scientist at Applied Research Lab, The Pennsylvania State University, Visiting Professor at The University of Memphis, USA, Research Scientist at University College London, U.K., Assistant Professor in Poland, and he also has industrial experience. Professor Eberbach's current work is in the areas of process algebras, resource bounded optimization, autonomous agents and mobile

robotics. General topics of interest are new computing paradigms, languages and architectures, distributed computing, concurrency and interaction, evolutionary computing and neural nets. More information about projects, publications, courses taught can be found at <http://cs.acadiau.ca/~eberbach>

October 27, 2000: Feng Zhao, Ph.D., Principal Scientist, Xerox PARC
“Smart Sensors, Collaborative Sensemaking”

Imagine a world in which we live where smart roads would be able to tell us when they need repair and which is the best direction to get to the Giants game, smart factories would stock up just enough inventory, ... The rapid advances in micro-electro-mechanical systems (MEMS) and lower-power wireless networking have enabled a new generation of tiny, cheap, networked sensors that can be “sprayed” on roads, across machines, and on walls. However, these massively distributed sensor networks must overcome a set of technological hurdles before they become widely deployable. Keeping up with the constant onslaught of sensory data from say 100,000 sensors is akin to drinking from a fire hose. The Xerox PARC Smart Matter Diagnostics and Collaborative Sensing Project studies the fundamental problems of distilling high-level, human-interpretable knowledge from distributed heterogeneous sensor signals in a rapid and scalable manner. We are developing powerful algorithms and software systems to enable a wide range of applications, from sensor-rich health monitoring of electro-mechanical equipment to human-aware environments that leverage sensors to support synergistic interactions with the physical world.

Biosketch:

Feng Zhao is a Principal Scientist in the Systems and Practices Laboratory at Xerox PARC. Dr. Zhao leads the Smart Matter Diagnostics Project that investigates how sensors and networking technology can change the way we build and interact with physical devices and environments. His research interest includes distributed sensor data analysis, diagnostics, qualitative reasoning, and control of dynamical systems. Dr. Zhao received his PhD in Electrical Engineering and Computer Science from MIT in 1992, where he developed one of the first algorithms for fast N-body computation and phase-space nonlinear control synthesis. From 1992 to 1999, he was Assistant and Associate Professor of Computer and Information Science at Ohio State University. His INSIGHT Group developed the SAL software tool for rapid prototyping of spatio-temporal data analysis applications; the tool is currently used by a number of other research groups. Currently, he is also Consulting Associate Professor of Computer Science at Stanford. Dr. Zhao was National Science Foundation and Office of Naval Research Young Investigator, and an Alfred P. Sloan Research Fellow in Computer Science. He has authored or co-authored about 50 peer-reviewed technical papers in the areas of smart matter, artificial intelligence, nonlinear control, and programming tools.

October 12, 2000: Irem Tumer, Intelligent Health and Safety Group - NASA/Ames
“Influence of Variations on Systems’ Performance And Safety”

High-risk aerospace components have to meet very stringent quality, performance, and safety requirements. Any source of variation is of concern, as it may result in scrap or rework (translating into production delays), poor performance (translating into customer dissatisfaction), and potentially unsafe flying conditions (translating into catastrophic failures). As part of the Intelligent

Health and Safety group, we have been designing controlled experiments to understand various sources of variations in helicopter transmissions, collecting vibration data, and analyzing the data for indicators of the variations. We are looking for normal and abnormal sources of variation that affect performance and indicators of these variations to provide warning about potential failures during flight. The experiments include:

- Flight tests using an AH-1 and an OH-58 helicopter, to determine the variations introduced due to regular maneuvering and the covariance with environmental conditions, engine torque, etc.;
- OH-58 transmission test-rig tests to determine the effect of variations due to different levels of torque, mast bending, and mast lifting forces, as well as pinion reinstallation effects;
- Machinery Fault Simulator tests to test the effect of prefabricated defects and inherent design and manufacturing variations on gears, bearings, etc.

In this talk, I will present an overview of our group's research goals, discuss the experiments and go over some of the results from the data analyses conducted so far. I will then discuss the current work and future directions in developing formalized methods for design and manufacturing engineers, using the variation information from empirical and analytical studies.

III.B RIACS-Supported Workshops

As part of its mission of fostering ties with the academic community in IT, RIACS provides financial, administrative, and technical support for selected workshops involving RIACS scientists. The following workshops were supported during this reporting year:

Workshop on Verification and Validation of Software

The RIACS Workshop on the Verification and Validation of Autonomous and Adaptive Systems took place at Asilomar Conference Center, Pacific Grove, CA, 5-7 Dec 2000. Discussions included: V&V of Intelligent Systems: How to verify and validate systems featuring some form of AI-based technique, such as model-based, rule-based or knowledge-based systems. V&V of Adaptive Systems: How to verify and validate systems featuring adaptive behavior, either in the form of parametric adaptation (e.g. neural nets, reinforcement learning) or control adaptation (e.g. genetic programming). V&V of Complex Systems: How to verify and validate systems with different interacting parts, either within a given location (e.g. layered control architectures) and among several locations (homogenous or heterogeneous multi-agent systems).

Workshop on Model-based Validation of Intelligence

Lina Khatib (Kestrel) and Charles Pecheur co-organized a symposium on “Model-based Validation of Intelligence” as part of the AAAI Spring Symposium Series in March 2001. We provided the technical content (announcement, reviews and selection of articles, final program) while AAAI provided the logistics (rooms, registration, etc.) A short report is due to appear in AAAI Magazine. We have managed the web pages for this event, including a repository of contributions from participants (<http://ase.arc.nasa.gov/mvi/>).

Workshop on NREN Mobile Networking

NREN hosted a workshop entitled “Mobile Terrestrial and Space Networking: Supporting the Scientific Community” in June 2001. Mobile networking will enable exciting new paradigms for NASA science and engineering, enhancing support for missions that extend into remote areas where it is not economically feasible to create a permanent wired communications infrastructure. NREN’s vision for the future is seamless integration of mobile networking technologies (including satellite communications, wireless networking, and sensor networks) to provide anytime, anywhere networking throughout the universe. Specific objectives of the workshop included:

- Characterize the various mobile/wireless/satellite technologies that are capable of supporting applications involving high-resolution multimedia
- Examine how heterogeneous networks can be integrated to form a seamless end-to-end path
- Identify how scientific applications will be enabled and enhanced by mobile terrestrial and space networking

M. Johnson was general chair of the workshop. The final report of the workshop is located at <http://www.nren.nasa.gov/workshop/workshop6.html>

III.C RIACS Technical Reports

01.01: Multiresolution Wavelet Based Adaptive Numerical Dissipation Control For Shock-Turbulence Computations

Authors: B. Sjogreen & H.C. Yee

Abstract:

The recently developed essentially fourth-order or higher low dissipative shock-capturing scheme of Yee, Sandham and Djomehri (1999) aimed at minimizing numerical dissipations for high speed compressible viscous flows containing shocks, shears and turbulence. To detect non-smooth behavior and control the amount of numerical dissipation to be added, Yee et al. employ an artificial compression method (ACM) of Harten (1978) but utilize it in an entirely different context than Harten originally intended. The ACM sensor consists of two tuning parameters and is highly physical problem dependent. To minimize the tuning of parameters and physical problem dependence, new sensors with improved detection properties are proposed. The new sensors are derived from utilizing appropriate non-orthogonal wavelet basis functions and they can be used to completely switch off the extra numerical dissipation outside shock layers. The non-dissipative spatial base scheme of arbitrarily high order of accuracy can be maintained at all parts of the domain where the solution is smooth. Two types of redundant non-orthogonal wavelet basis functions are considered. One is the B-spline wavelet (Mallat & Zhong 1992) used by Gerritsen & Olsson (1996) in an adaptive mesh refinement method, to determine regions where refinement should be done. The other is the modification of the multiresolution method of Harten (1995) by converting it to a new, redundant, non-orthogonal wavelet. The wavelet sensor is then obtained by computing the estimated Lipschitz exponent of a chosen physical quantity (or vector) to be sensed on a chosen set of wavelet basis functions. Both wavelet sensors can be viewed as dual-purpose adaptive methods leading to dynamic numerical dissipation control and improved grid adaptation indicators.

Consequently, they are useful not only for shock-turbulence computations but also for numerical combustion and computational aeroacoustics.

In addition, these sensors are scheme independent and can be stand alone options for numerical algorithm other than the Yee et al. scheme.

01.02: High Order Numerical Simulation of Sound Generated by the Kirchhoff Vortex

Authors: B. Muller and H.C. Yee,

Number of Pages: 9 (European size)

Publication: Proceedings of the AMIF 2nd International Conference, Oct. 12-14, 2000, Tuscany, Italy

Abstract:

An improved high order finite difference method for low Mach number computational aeroacoustics (CAA) is described. The improvements involve the conditioning of the Euler equations to minimize numerical cancellation errors, and the use of a stable non-dissipative sixth-order central spatial interior scheme and a third-order boundary scheme. Spurious high frequency oscillations are damped by a fourth-order characteristic-based filter.

The objective of this paper is to apply these improvements in the simulation of sound generated by the Kirchhoff vortex.

01.03: UNUSED

01.04: Sound Emission of Rotor Induced Deformations of Generator Casings

Authors: W. Polifke, B. Müller and H.C. Yee, March 2001

Abstract:

The casing of large electrical generators can be deformed slightly by the rotor's magnetic field. The sound emission produced by these periodic deformations, which could possibly exceed guaranteed noise emission limits, is analyzed analytically and numerically. From the deformation of the casing, the normal velocity of the generator's surface is computed. Taking into account the corresponding symmetry, an analytical solution for the acoustic pressure outside the generator is found in terms of the Hankel function of second order. The normal velocity of the generator surface provides the required boundary condition for the acoustic pressure and determines the magnitude of pressure oscillations. For the numerical simulation, the nonlinear 2D Euler equations are formulated in a perturbation form for low Mach number Computational Aeroacoustics (CAA). The spatial derivatives are discretized by the classical sixth-order central interior scheme and a third-order boundary scheme.

Spurious high frequency oscillations are damped by a characteristic-based artificial compression method (ACM) filter. The time derivatives are approximated by the classical 4th-order Runge-Kutta method. The numerical results are in excellent agreement with the analytical solution.

01.05: Addressing Dynamic Issues of Program Model Checking

Authors: Flavio Lerda & Willem Visser

Abstract:

Model checking real programs, has recently become an active research area. Programs however exhibit two characteristics that make model checking difficult: the complexity of their state and the dynamic nature of many programs. Here we address both these issues within the context of the Java PathFinder (JPF) model checker. Firstly, we will show how the state of a Java program can be encoded efficiently and how this encoding can be exploited to improve model checking. Next we show how to use symmetry reductions to alleviate some of the problems introduced by the dynamic nature of Java programs. Lastly, we show how distributed model checking of a dynamic program can be achieved, and furthermore, how dynamic partitions of the state space can improve model checking. We support all our findings with results from applying these techniques within the JPF model checker.

01.06: Grid Convergence Of High Order Methods For Multiscale Complex Unsteady Viscous Compressible Flows

*Authors: B. Sjogreen Department of Numerical Analysis and Computer Sciences KTH
100 44 Stockholm, Sweden and H.C. Yee, NASA Ames Research Center Moffett Field, CA 94035*

Number of Pages: 24, April 2001

Publication: AIAA Paper 2001-2274, Proceedings of the 15th AIAA CFD

Conference: June 11-14, 2001, Anaheim, CA.

Abstract:

Grid convergence study of several high order methods for the computations of rapidly developing complex unsteady viscous compressible flows with a wide range of physical scales are compared. The recently developed adaptive numerical dissipation control high order methods referred to as the ACM and wavelet filter schemes are compared with a fifth-order weighted ENO (WENO) scheme. The two 2-D compressible full Navier-Stokes models considered do not possess known analytical and experimental data. Fine grid solutions from standard second-order TVD scheme and MUSCL scheme with limiters are used as reference solutions. The first model is a 2-D viscous analogue of a shock tube problem, which involves complex shock/shear/boundary-layer interactions. The second model is a supersonic reactive flow concerning fuel breakup. The fuel mixing involves circular hydrogen bubbles in air interacting with a planar moving shock wave. Both models contain fine scale structures and are stiff in the sense that even though the unsteadiness of the flows are rapidly developing, extreme grid refinement and time step restriction are needed to resolve all the flow scales as well as the chemical reaction scales.

01.07: Design and Control of Large Collections of Learning Agents

Author: Adrian Agogino, April 19, 2001

Number of Pages: 11

Abstract:

The intelligent control of multiple autonomous agents is an important yet difficult task. Previous methods used to address this problem have proved to be either too brittle, too hard to use, or not scalable to large systems. The "Collective Intelligence" project at NASA/Ames provides an elegant, machine-learning approach to address these problems. This approach mathematically defines some essential properties that a reward system should have to promote coordinated behavior among reinforcement learners. My work has focused on creating additional key properties and algorithms within the mathematics of the Collective Intelligence framework. One of the additions will allow agents to learn more quickly, in a more coordinated manner. The other will let agents learn with less knowledge of their environment. These additions will allow the framework to be applied more easily, to a much larger domain of multi-agent problems.

01.08: Testing Linear Temporal Logic Formulae on Finite Execution Traces

Authors: Klaus Havelund, QSS / Recom Technologies, NASA Ames Research Center and Grigore Rosu Research Institute for Advanced Computer Science NASA Ames Research Center

Number of Pages: 15

Abstract:

We present an algorithm for efficiently testing Linear Temporal Logic (LTL) formulae on finite execution traces. The standard models of LTL are infinite traces, enacting the behavior of reactive and concurrent systems which conceptually may be continuously alive. In most past applications of LTL, theorem provers and model checkers have been used to formally prove that down-scaled models satisfy such LTL specifications. Our goal is instead to use LTL for up-scaled testing of real software applications, corresponding to analyzing the conformance of finite traces against LTL formulae. We first describe what it means for a finite trace to satisfy an LTL property and then

suggest an optimized algorithm based on transforming LTL formulae. We use Maude, which turns out to be a good notation and an efficient-rewriting engine for performing these experiments.

01.09: Redirecting by Injector

Authors: Robert E. Filman (RIACS) and Diana D. Lee (SAIC)

Number of Pages: 6

Publication: Proceedings of the 21st IEEE Intl., Conference: Distributed Computing Systems, Vol 2 Workshops: International Workshop on Distributed Dynamic Multiservice Architectures, Phoenix, Arizona, April 2001, pp.141-146.

Abstract:

We describe the Object Infrastructure Framework, a system that seeks to simplify the creation of distributed applications by injecting behavior on the communication paths between components. We touch on some of the utilities and services that can be achieved with injector technology, and then focus on the uses of redirecting injectors, injectors that take requests directed at a particular server and generate requests directed at others. We close by noting that OIF is an Aspect-Oriented Programming system, and comparing OIF to related work.

01.10: A Software Architecture for Intelligent Synthesis Environments

Author: Robert E. Filman (RIACS)

Number of pages: 9

Proc. 2001 IEEE Aerospace Conference, Big Sky, Montana, March 2001.

Abstract:

NASA's Intelligent Synthesis Environment (ISE) program is a grand attempt to develop a system to transform the way complex artifacts are engineered. This paper discusses a "middleware" architecture for enabling the development of ISE. Desirable elements of such an Intelligent Synthesis Architecture (ISA) include remote invocation; plug-and-play applications; scripting of applications; management of design artifacts, tools, and artifact and tool attributes; common system services; system management; and systematic enforcement of policies. A typical middleware foundation for an ISA is a distributed object technology such as CORBA (Common Object Request Broker Architecture). I argue that such an architecture can be profitably extended by enabling "plug-and-play" insertion of new policies into the system. I describe the Object Infrastructure Framework, an Aspect Oriented Programming (AOP) environment for developing distributed systems that provides policy insertion. This technology can be used to enforce policies such as maintaining the annotations of artifacts, particularly the provenance and access control rules of artifacts; performing automatic data type transformations between representations; supplying alternative servers of the same service; reporting on the status of jobs and of the system; conveying privileges throughout an application; supporting long-lived transactions; maintaining version consistency; and providing software redundancy and mobility.

01.11: Managing Distributed Systems with Smart Subscriptions,

Authors: Robert E. Filman (RIACS) and Diana D. Lee (SAIC) Number of pages: 7

Proc. International Conference on Parallel and Distributed Processing Techniques and Applications (PDPTA'2000), Las Vegas, June 2000, pp.853-860.

Abstract:

We describe an event-based, publish-and-subscribe system based on using “smart subscriptions” to recognize weakly structured events. We present a hierarchy of subscription languages (propositional, predicate, temporal and agent) of increasing expressability and computational complexity, and several algorithms (Sig, Memo, Lattice, Compile and RETE) for efficiently recognizing event matches. We have applied this system to implementing and managing distributed applications.

01.12: Aspect-Oriented Programming is Quantification and Obliviousness,

Authors: Robert E. Filman (RIACS) and Daniel P. Friedman (Indiana University, Bloomington)

Number of pages: 7

Workshop on Advanced Separation of Concerns, OOPSLA 2000, October 2000, Minneapolis.

Abstract:

This paper proposes that the distinguishing characteristic of Aspect-Oriented Programming (AOP) systems is that they allow programming by making quantified programmatic assertions over programs written by programmers oblivious to such assertions. Thus, AOP systems can be analyzed with respect to three critical dimensions: the kinds of quantifications allowed, the nature of the actions that can be asserted, and the mechanism for combining base-level actions with asserted actions. Consequences of this perspective are the recognition that certain systems are not AOP and that some mechanisms are expressive enough to allow programming an AOP system within them. A corollary is that while AOP can be applied to Object-Oriented Programming, it is an independent concept applicable to other programming styles.

01.13: Applying Aspect-Oriented Programming to Intelligent Synthesis,

Author: Robert E. Filman (RIACS)

Number of pages: 6

Workshop on Aspects and Dimensions of Concerns, 14th European Conference on Object-Oriented Programming, Cannes, France, June 2000.

Abstract:

I discuss a component-centered, aspect-oriented system, the Object Infrastructure Framework (OIF), NASA’s initiative on Intelligent Synthesis Environments (ISE), and the application of OIF to the architecture of ISE.

01.14: What Is Aspect-Oriented Programming, Revisited

Author: Robert E. Filman (RIACS)

Number of pages: 7

Workshop on Advanced Separation of Concerns, 2001 European Conference on Object-Oriented Programming, Budapest

Abstract:

For the Advanced Separation of Concerns workshop at OOPSLA 2000 in Minneapolis, Dan Friedman and I wrote a paper [39] that argued that the distinguishing characteristic of Aspect-Oriented Programming systems (qua programming systems) is that they provide quantification and obliviousness. In this paper, I expand on the themes of our Minneapolis workshop paper, respond

to some of the comments we've received on that paper, and provide a computational formalization of the notion of quantification.

01.15: Synthesizing Dynamic Programming Algorithms from Linear Temporal Logic Formulae

Authors: Grigore Rosu Research Institute for Advanced Computer Science, NASA Ames Research Center, and Klaus Havelund QSS / Recom Technologies, NASA Ames Research Center
Number of pages: 11

Abstract:

The problem of testing a linear temporal logic (LTL) formula on a finite execution trace of events, generated by an executing program, occurs naturally in runtime analysis of software. We present an algorithm, which takes an LTL formula and generates an efficient dynamic programming algorithm. The generated algorithm tests whether the LTL formula is satisfied by a finite trace of events given as input. The generated algorithm runs in linear time, its constant depending on the size of the LTL formula. The memory needed is constant, also depending on the size of the formula.

01.16: Interpreting Abstract Interpretations in Membership Equational Logic

Authors: Bernd Fischer Research Institute for Advanced Computer Science, NASA Ames Research Center, and Grigore Rosu Research Institute for Advanced Computer Science, NASA Ames Research Center
Number of pages: 15

Abstract:

We present a logical framework in which abstract interpretations can be naturally specified and then verified. Our approach is based on membership equational logic, which extends equational logics, by membership axioms, asserting that a term has a certain sort. We represent an abstract interpretation as a membership equational logic specification, usually as an overloaded order-sorted signature with membership axioms. It turns out that, for any term, its least sort over this specification corresponds to its most concrete abstract value. Maude implements membership equational logic and provides mechanisms to calculate the least sort of a term efficiently. We first show how Maude can be used to get prototyping of abstract interpretations for free. Building on the meta-logic facilities of Maude, we further develop a tool that automatically checks an abstract interpretation against a set of user-defined properties. This can be used to select an appropriate abstract interpretation, to characterize the specific loss of information during abstraction, and to compare different abstractions with each other.

01.17: Low Dissipative High Order Numerical Simulations of Supersonic Reactive Flows

Authors: B. Sjogreen, Department of Numerical Analysis and Computer Sciences KTH 100 44 Stockholm, Sweden and H.C. Yee, NASA Ames Research Center, Moffett Field, CA 94035, USA
Number of pages: 22

Publication: Proceedings of the ECCOMAS - CFD Conference, September 4-7, 2001, Swansea, Wales, UK

Abstract:

The performance of several high order finite difference methods for a 2-D flow consisting of a planar Mach 2 shock in air interacting with a circular zone of hydrogen bubbles in two different initial configurations is discussed. The two initial configurations are a single bubble and two non-aligned bubbles. The gradient in pressure across the shock in conjunction with the gradient in fluid density between the air and hydrogen produce a large increase in vorticity as the shock passes through the hydrogen fuel. As can be seen in the study of Don & Quillen (1995), Don & Gottlieb (1998) and the present grid convergence study, the size, spacing and velocity of the vortical structures are very difficult to accurately simulate numerically.

01.18: The AutoBayes Program Synthesis System - System Description

Authors: Bernd Fischer / RIACS, Thomas Pressburger / NASA, Grigore Rosu / RIACS, and Johann Schumann / RIACS

Abstract:

Autobayes is a fully automatic program synthesis system for the statistical data analysis domain. Its input is a concise description of a data analysis problem in the form of a statistical model; its output is optimized and fully documented C/C++ code, which can be linked dynamically into the Matlab and Octave environments. Autobayes synthesizes code by a schema-guided deductive process. Schemas (i.e., code templates with associated semantic constraints) are applied to the original problem and recursively to emerging subproblems. Autobayes complements this approach by symbolic computation to derive closed-form solutions whenever possible. In this paper, we concentrate on the interaction between the symbolic computations and the deductive synthesis process.

01.19: Monitoring Java Programs with Java PathExplorer

Authors: Klaus Havelund / Kestrel Technology and Grigore Rosu / RIACS

Abstract:

We present recent work on the development of Java PathExplorer (JPaXX), a tool for monitoring the execution of Java programs. JPaX can be used during program testing to gain increased information about program executions, and can potentially furthermore be applied during operation to survey safety critical systems. The tool facilitates automated instrumentation of a program's byte code, which will then emit events to an observer during its execution.

The observer checks the events against user provided high-level requirement specifications, for example temporal logic formulae, and against lower level error detection procedures, usually concurrency related such as deadlock and data race algorithms. High level requirement specifications together with their underlying logics are defined in rewriting logic using Maude, and then can either be directly checked using Maude rewriting engine, or be first translated to efficient data structures and then checked in Java.

01.20: Workshop on the Verification and Validation of Autonomous and Adaptive Systems

Authors: Charles Pecheur , Willem Visser, RIACS/NASA Ames and Reid Simmons, Carnegie Mellon University

Number of pages: 11 pages

RIACS Workshop, and to appear as a conference report in AI Magazine

Abstract:

The long-term future of space exploration at NASA is dependent on the full exploitation of autonomous and adaptive systems: careful monitoring of missions from earth, as is the norm now, will be infeasible due to the sheer number of proposed missions and the communication lag for deep-space missions. Mission managers are however worried about the reliability of these more intelligent systems. The main focus of the workshop was to address these worries and hence we invited NASA engineers working on autonomous and adaptive systems and researchers interested in the verification and validation (V&V) of software systems. The dual purpose of the meeting was to (1) make NASA engineers aware of the V&V techniques they could be using and (2) make the V&V community aware of the complexity of the systems NASA is developing.

01.21: Automata-Based Verification of Temporal Properties on Running Programs

Authors: Dimitra Giannakopoulou, RIACS/NASA Ames, and Klaus Havelund, Kestrel, Technologies/NASA Ames

Number of pages: 9

Abstract:

This paper presents an approach to checking a running program against its Linear Temporal Logic (LTL) specifications. LTL is a widely used logic for expressing properties of programs viewed as sets of executions. Our approach consists of translating LTL formulae to finite-state automata, which are used as observers of the program behavior. The translation algorithm we propose modifies standard LTL to Büchi automata conversion techniques to generate automata that check finite program traces. The algorithm has been implemented in a tool, which has been integrated with the generic JpaX framework for runtime analysis of Java programs.

01.22: D3: A Collaborative Infrastructure for Aerospace Design

Joan Walton (NASA Ames), Robert E. Filman (RIACS), Chris Knight (NASA Ames), David J. Kormsmeier (NASA Ames), and Diana D. Lee (SAIC)

Number of pages: 8

Workshop on Advanced Collaborative Environments, San Francisco, August, 2001

Abstract:

DARWIN is a NASA developed, Internet-based system for enabling aerospace researchers to securely and remotely access and collaborate on the analysis of aerospace vehicle design data, primarily the results of wind-tunnel testing and numeric (e.g., computational fluid-dynamics) model executions. DARWIN captures, stores and indexes data; manages derived knowledge (such as visualizations across multiple datasets); and provides an environment for designers to collaborate in the analysis of test results. DARWIN is an interesting application because it supports high-volumes of data, integrates multiple modalities of data display (e.g., images and data visualizations), and provides non-trivial access control mechanisms. DARWIN enables collaboration by allowing not only sharing visualizations of data, but also commentary about and views of data.

We are currently developing D3, the third generation of DARWIN. Earlier versions of DARWIN were characterized by browser-based interfaces and a hodge-podge of server technologies: CGI scripts, applets, PERL, and so forth. But browsers proved difficult to control, and a proliferation of computational mechanisms proved inefficient and difficult to maintain. D3 substitutes a pure-Java approach for that medley: A Java client communicates (though RMI over HTTPS) with a

Java-based application server. Code on the server accesses information from JDBC databases, distributed LDAP security services, and a collaborative information system (CORE, a successor of PostDoc.) D3 is a three tier-architecture, but unlike “E-commerce” applications, the data usage pattern suggests different strategies than traditional Enterprise Java Beans we need to move volumes of related data together, considerable processing happens on the client, and the “business logic” on the server-side is primarily data integration and collaboration. With D3, we are extending DARWIN to handle other data domains and to be a distributed system, where a single login allows a user transparent access to test results from multiple servers and authority domains.

01.23: Entropy Splitting for High Order Numerical Simulation of Vortex Sound at Low Mach Numbers

Authors: Bernhard Müller, Department of Scientific Computing, Information Technology, Uppsala University, S-751 04, Uppsala, Sweden and H.C. Yee, NASA Ames Research Center, Moffett Field, CA 94035, USA

Number of pages: 12

Publication: Proceedings of the 5th ICOSAHOM-01, June 11-15, 2001, Uppsala, Sweden

Abstract:

Several recent developments in efficient, stable, highly parallelizable high order non-dissipative spatial schemes with characteristic based filters that exhibit low dissipation for long time linear and nonlinear wave propagations are utilized for computational aeroacoustics (CAA). For stability consideration, the Euler equations are split into a conservative and a symmetric non-conservative portion. Due to the large disparity of acoustic and stagnation quantities in low Mach number aeroacoustics, the split Euler equations are formulated in perturbation form to minimize numerical cancellation errors. Spurious oscillations are suppressed by a characteristic-based filter. The method has been applied to accurately simulate the sound emitted by an almost circular Kirchhoff vortex at low Mach numbers.

01.24: Adaptive Numerical-Dissipation/Filter Controls For High Order Numerical Methods

Authors: H.C. Yee, NASA Ames Research Center, Moffett Field, CA 94035, USA and

B. Sjögren, Department of Numerical Analysis and Computer Sciences KTH, 100 44 Stockholm, Sweden

Number of pages: 16

Publication: Proceedings of the Third AFOSR International Conference on DNS/LES, Arlington, Texas, August 4-9, 2001

Abstract:

Proper control of the numerical-dissipation/filter to accurately resolve all relevant multiscales of complex flow problems while still maintaining nonlinear stability and efficiency for long-time numerical integrations poses a great challenge to the design of numerical methods. The required type and amount of numerical-dissipation/filter are not only physical problem dependent, but also vary from one flow region to another. An approach for the automatic detection of different flow features as distinct sensors to signal the appropriate type and amount of numerical-dissipation/filter for non-dissipative high order schemes is proposed. These scheme-independent sensors are capable of distinguishing shocks/shears, turbulent fluctuations and spurious high-frequency oscillations. In addition, these sensors are readily available as an improvement over

existing grid adaptation indicators. The same shock/shear detector that is designed to switch on the shock/shear numerical dissipation can be used to switch off the entropy splitting form of the inviscid flux derivative in the vicinity the discontinuous regions to further improve nonlinear stability and minimize the use of numerical dissipation. The rest of the sensors in conjunction with the local flow speed and Reynolds number can also be used to adaptively determine the appropriate entropy splitting parameter for each flow type/region.

The goal of this paper is to further improve nonlinear stability, accuracy and efficiency of long-time numerical integration of complex shock/turbulence/acoustics interactions and numerical combustion. The minimization of employing very fine grids to overcome the production of spurious numerical solution and/or instability due to under-resolved grids is also sought.

IV RIACS Staff

The primary mechanism used at RIACS is the engagement of RIACS scientists in NASA projects. RIACS staff scientists are recruited from the broad university research community to provide a nucleus of activity to both collaborate with NASA scientists and to provide an “attraction point” for bringing in visitors from academia. These scientists typically work in clusters on NASA projects – collaborating closely with NASA scientists and onsite contractors, providing senior technical expertise and coordinating visitors from academia.

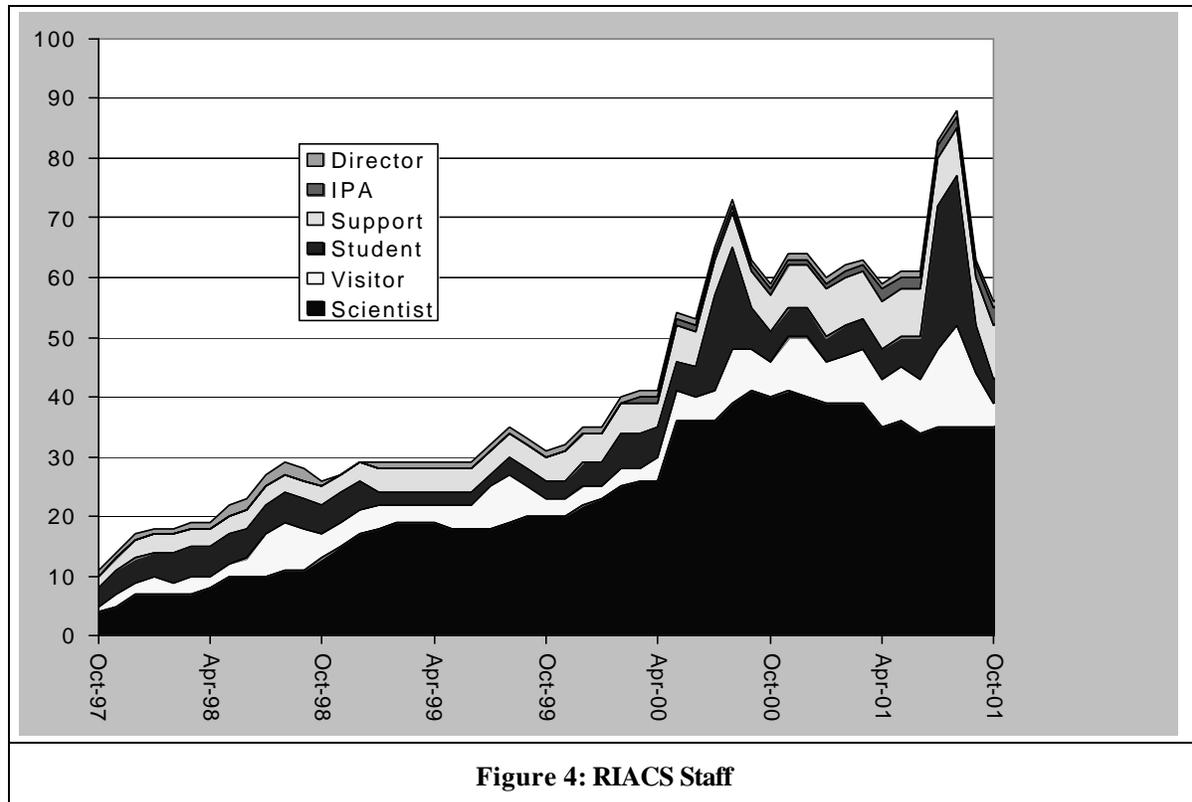


Figure 4 shows the growth in RIACS staff from 1997 through the reporting period. Over the period of the current Cooperative Agreement shown, the number of scientific staff onsite has grown from three to a current 35 permanent scientific staff members., Three scientists, Daniel Clancy, Butler Hine, and David Maluf, are now on loan to NASA under the IPA program. 39 visiting scientists and 21 visiting students spent time at RIACS during the year.

The following sections lists both the permanent and visiting staff at RIACS over the reporting period, with the time they have been at RIACS shown in parentheses.

IV.A *Management Staff*

Barry Leiner, Director – Ph.D. Electrical Engineering, Stanford University, 1973. (06/28/99 – present)

Robert Morris, Deputy Director – Ph.D., Philosophy, Indiana University, 1984. (8/2/99 – 3/1/01)

Kathleen Connell, Associate Director – BA, Human and Organizational Development, UC Berkeley, Strategic planning for the leveraging of advanced information technology in astrobiology and space science research. (4/1/01 – present)

Kanna Rajan, Associate Director – MA, 1989, Computer Science, New York University, Automated reasoning, planning and scheduling. Model-based reasoning, knowledge representation and space craft autonomy. (04/03/00 – present)

Johann Schumann, Associate Director – Ph.D, 1991, Computer Science, Technical University of Munich, Germany (Neural networks, automated theorem, parallel symbolic systems (03/03/00 – present)

IV.B Administrative and Support Staff

Diana Martinez, Administrator (08/18/97 - present)

Roscoe “Jack” Jackson Executive Assistant (10/10/00 - present)

Beatrice Burnett, Administrative Assistant (11/3/97 - present)

Sue Christman, Administrative Assistant (4/06/00-present)

Charlene Daley Administrative Assistant (12/26/00 – present)

Karen Brennan, Administrative Assistant Intern, DeAnza College (7/02/01 – present)

Peggy Leising, Project Facilitator (04/01/00 – present)

Ryan Nelson, Systems Administrator (subcontractor) (6/17/00 – present)

Rasheeda Shaheed, Administrative Assistant (04/16/99 – 7/10/2001)

IV.C Scientific Staff

Linda Andrews, BS, 1990, San Jose State University, Orchestrate and coordinate research program into information and knowledge management. (6/20/01 – present)

Anupa Bajwa, Ph.D., 1995, Aerospace Engineering, Pennsylvania State University, Model-based reasoning for autonomous systems diagnosis. (04/03/00 – present)

Esfandiar Bandari, Ph.D, 1995, Computer Science, University of British Columbia, Computational Vision, Signal Processing, 3-D Reconstruction and Medical Imaging (09/2/98 – present)

Walter F. Brooks, Ph.D., 1977, Physics, Stevens Institute of Technology, Advanced air traffic control, advanced information systems technology in support of Earth Science Enterprise. (04/04/00 – present)

Peter J. Cheeseman, Ph.D., 1979, Monash University, Artificial Intelligence, computational complexity, bayesian inference, computer vision, plasma physics (09/1/97-present)

Rei J. Cheng, BS, 1973, Pharmacy, Taipei Medical College, 3-D scientific visualization and medical visualization (09/1/98 – 5/5/01)

Daniel J. Clancy, Ph.D., 1997, Computer Science, University of Texas, Austin. Model-based reasoning, artificial intelligence, diagnosis, health management (01/24/00 – present, IPA)

Richard Dearden, Ph.D., 2000, Computer Science, University of British Columbia. Artificial intelligence, reasoning, and decision making under uncertainty (07/19/00 – present)

John Dowding, MSE, 1988, Computer Science, University of Pennsylvania, Spoken dialogue systems, speech recognition, language processing (9/18/00 – present)

Lisa Faithorn, Ph.D, 1990, Anthropology, University of Pennsylvania, Technology enhanced group communication, collaboration and scientific research, human dimensions and technology options. (9/18/00 – present)

Robert E. Filman, Ph.D., 1979, Computer Science, Stanford University. Frameworks for distributed computing. (12/01/99 – present)

Bernd Fischer, Ph.D., 1998, TU Braunschweig, Germany, Computer Science (11/01/98 – present)

Andreas Frank, Ph.D., 1999, Biomedical Engineering, University of Texas, Arlington. Numerical and mathematical modeling of biological tissue. (11/17/99 – 11/13/00)

Dave Gehrt, JD Law, 1972, University of Washington, UNIX system administration, security, and network based tools (1/84 - 7/85, 2/1/88 - present).

Dimitra Giannakopoulou, Ph.D, 1999, Distributed Software Engineering, Imperial College, London, Distributed computing, design, analysis and implementation (8/28/00 – present)

Zann Gill, M.Arch, 1979, Harvard University, Collaborative problem-solving environments (CPSE), concept formation (the creative process). (03/07/00 – present)

Howard Goldstein, 1963, MS, Chemical Engineering, University of Arizona, Research on thermal protection systems that utilize intelligent systems technology and smart materials (7/1/00 – present)

Jon Guice, Ph.D., 1997, Sociology (Science Studies, University of California, San Diego. Research and development management, technology strategy. (04/01/00 – 01/07/01)

James Hieronymus, Ph.D., 1971, Applied Physics, Cornell University, Spoken Dialogue System, automated speech recognition, acoustic phonetics. (11/1/00 – present)

Butler Hine, Ph.D., 1988, Astronomy, University of Texas, Austin. Autonomous Systems for Space and Planetary Exploration. (11/01/99 – present, IPA)

Beth Ann Hockey, Ph.D., 1998, Linguistics, University of Pennsylvania, (01/01/99 – present)

Frances H. James, Ph.D., 1998, Computer Science, Stanford University, Speech understanding technologies and applications, developing interfaces using speech. (7/13/98 – 3/16/01)

Marjory J. Johnson, Ph.D., 1970, Mathematics, University of Iowa, High-performance networking for both space and ground applications (1/9/84 - present).

Ari K. Jonsson, Ph.D., 1997, Computer Science, Stanford University, New Techniques in constraint satisfaction and Automated Planning. (10/1/97 - present)

Frank Kuehnel, Ph.D, 2000, Physics, Michigan State University, Computervision in 3D super-resolution and artificial intelligence. (08/01/00 - present)

John Loch, Ph.D., 1998, Computer Science, University of Colorado at Boulder (12/28/98 – present)

David Maluf, Ph.D., McGill University, Canada, 1995, Post Doctoral Fellow, Stanford University, knowledge-based systems, database management systems, image databases, computer vision, and man machine interfaces. (01/03/00 – present, IPA)

Robin D. Morris, Ph.D., 1995, Engineering, Trinity College, Cambridge, U.K., Bayesian Inference and Image Analysis, Mathematical Modeling of Natural Imagery and Associated Computational Methods. (3/1/98 – present)

John O'Neill, Ph.D., 1997, Computing, Royal Melbourne Institute of Technology (12/01/98 – 12/18/00)

Seungjoon Park, Ph.D., 1996, Electrical Engineering, Computer Science, Stanford University (10/01/98 – 7/27/01)

Lewis Peach – USRA Chief Engineer (09/04/99 – present)

Charles Pecheur, Ph.D., 1996, Electrical Engineering, Computer Science, University of Liege, (11/06/98 – present)

Grigore Rosu, Ph.D, 2000, Computer Science, University of California, San Diego Formal methods in system specification and verification, applied logics in computer science. (9/1/00 – present)

Matthias Schmidlin, M.Sc., 1994, Technology Management, John Moores University, Liverpool. Organizational Aviation Safety and its Economical Implications (03/01/00 – 5/8/01)

Karl Schweighofer, Ph.D, 1995, Chemistry, UCSC. Research in structural genomics /bioinformatics (8/1/01 - present)

Maarten Sierhuis, MS, 1986, Engineering, Mague Polytechnic University, Intelligent multi-agent simulation agent-oriented programming languages (4/1/98 – present)

Mahadevan Subramaniam, Ph.D., 1996, Computer Science, State University of New York, Albany, Formal methods, verification of hw/sw, and software engineering processes (07/05/00 – 3/15/01)

Jean Jerry Toung, MS, 2000, Electrical Engineering and Computer Science, Universite de Nantes, France, High performance WAN network monitoring and technology deployment for the NGI/NREN project. (07/15/00 – present)

Ian A. Twombly, Ph.D., 1997, Biophysics, John Hopkins University, (9/1/98 – present)

Willem Visser, Ph.D., 1998, Computer Science, University of Manchester (10/19/98 – present)

Udo von Toussaint Ph.D., 2000, Physics, University of Bayreuth, Germany, Bayesian inference on ill-posed inverse problems. (1/2/01 – present)

Richard Washington, Ph.D., 1994, Computer Science, Stanford University. Artificial Intelligence, Robotics, Autonomous Systems, Plan Execution. (04/03/00 – present)

IV.D Visiting Scientists and Consultants

Note: Dates shown for visiting scientists are not necessarily continuous.

Remi Abgrall, Ph.D., 1988, University of Paris VI, Numerical solution of system of conservation laws on irregular domain and meshes.. (6/15/01 – 8/11/01)

Jason Baldrige, MSC, 1998, Computer Science, University of Edinburgh, Computational models of natural language syntax. (6/20/01 – 9/14/01)

Marsha Berger, Ph.D., 1982, New York University, Courant Institute, Computer Science, Automated mesh generation and flow computations using Cartesian embedded boundary approach (6/12/01 – 8/22/01)

Wray Buntine, Ph.D., 1991, University of Technology, Sydney, Australia, Computational statistics, artificial intelligence, and computation with probabilities, implementation of learning algorithms. (11/30/00 – 12/03/00)

James Crawford, Ph.D., University of Texas, Austin, Knowledge representation, scheduling, supply chain planning. (8/23/01 – 8/24/01)

Suhrit Dey, Ph.D., 1970, Aerospace Engineering, Mississippi State University, Hemodynamics of breast Cancer. (3/1/02-7/31/01)

Michael Duke, Ph.D., 1963, Geochemistry, California Institute of Technology, Moon and Mars Geoscience; exploration and development of space resources (5/1/01 – present)

Tarek El-Ghazawi, Ph.D., George Mason University, Distributed Shared-memory Programming with the Unified Parallel C Information Power Grid, (09/21/00 – present)

Daniel Hammerstrom, Ph.D., 1977, EE University of Illinois. Oregon Graduate Institute. Massively parallel VLSI architectures for intelligent systems. (03/01/00 - present)

Richard G. Johnson, Ph.D. - Physics, Indiana University, 1956, Global environmental problems and issues (11/1/92 - present).

Claude Kirchner, Ph.D. - Computer Science, NANCY INRIA, France, Logical frameworks based on rewriting calculus for the mechanization of deduction and computation. (7/16/01 – 7/20/01)

Helene Kirchner, Ph.D. - Computer Science, NANCY, CNRS France, Rule based programming and proving formal specifications and software validations. (7/16/01 – 7/20/01)

Mats. G. Larsson, Ph.D., 1997, Applied Mathematics, Chalmers Technical University, Sweden. Numerical solution of partial differential equations. (8/13/01 – 9/07/01)

Dohyung Lee, Ph.D., 1996, Aerospace Engineering, University of Michigan. Multi-resolution for Computational Fluid Dynamics. (1/21/01 – 3/02/01)

Stacy Marsella, Ph.D., Computer Science, Rutgers, Multi-agent teamwork computations models of cognition and social reasoning. (5/2/01 – 5/4/01)

David Marshall, MS, 1995, Aerospace Engineering, Georgia Institute of Technology, Develop algorithms for language distributed memory architectures. (6/4/01 – 6/29/01)

Bruce Methven, JD, 1980, Boalt Hall School of Law, UC Berkeley. Business development report for IASC (6/28/01 – 9/1/01)

Brian Murphy, B.S., Physics, Stanford University, Quantum computing algorithms and architectures. (10/00 – present)

Marian Nemec, MS, 1999, Aerospace Science & Engineering, University of Toronto, Development of accurate and efficient algorithms for aerodynamic shape optimization problems. (7/23/01 – 7/27/01)

David M. Rosen, BA, 1973, Philosophy, City College of New York. Assess business-government partnership models and produce a business development report. (7/1/01 – 9/1/01)

Elizabet Sahtouris, Ph.D., 1964, Physiological Psychology and Evolutionary Biology, Syracuse University, New frontiers in evolution biology (7/1/01 – 9/01/01)

Bjorn Sjogreen, Ph.D., 1988, Numerical Analysis, Uppsala University, Sweden, Construction of accurate and efficient numerical methods for computation of compressible fluid flow. (10/15/00-8/23/01)

David H. Smith, Ph.D., 1995, Mathematics, University of Queensland. Numerical computation with scientific and engineering applications. Bifurcation analysis and computation. (2/5/01 – 3/16/01)

Sheridan M. Tatsuno, MS, 1977, Planning and Public Policy, Harvard's Kennedy School of Government, Dreamscape Global, Development of an organizational outline for an innovative NASA-industry collaborative problem-solving environment (CPSG) for adoption by IASC. (7/11/01 – 9/01/01)

Sankaran Venkateswaran, Ph.D. -Sr. Research Associate, University of Tennessee Space Institute, preconditioning methods and use of neural networks for application to semi-conductor materials (5/18/98 – present)

Simon Wildermuth, MD, University of Zurich, Switzerland, Clinical radiological database and medical image post-processing. (03/10/00 – present)

David Zingg, Ph.D., University of Toronto, Aerospace Engineering, Navier-Stokes equations (07/01/00 – 09/30/00) (7/1/01 - 9/28/01)

IV.E Visiting Students

Alessandro Acquisti, MS, Information Management, University of California, Berkeley, Simulating work practices using Brahms agent-oriented language. (1/16/01 – present)

Adrian Agogino, MS, 1999, Electrical Engineering, University of Texas, Agents Controlled by neural networks and collective algorithms (06/19/00 – 08/31/00) (6/4/01 – 8/17/01)

Jason Baldrige, MS, Computer Science, University of Edinburgh, Theoretical Syntax and Natural Language Processing (07/17/00 – 09/22/01)

Ralph Benzinger, MS, Computer Science, Cornell University, Computational Type Theory, Applied Logic, Constructive Mathematics (06/12/00 – 6/15/01)

Kristin Branson, BA, 2000, Computer Science, Harvard University, Automatic scheduling of earth-observing satellite telescopes. (06/19/00 – 08/31/00)(6/25/01 – 9/3/01)

Karen Brennan, Accounting, DeAnza College, NASA Internship Program, (7/2/01 – present)

Mary Ellen Campana, MS, 2001, Computer Science, University of Rochester (5/23/01 – 8/3/01)

Matthew Deans, Ph.D, 2001, Robotics, Carnegie Mellon, Mobile robotics, localization and mapping. (6/4/01 – 8/10/01)

Judah dePaula, BS, 2001, Computer Science, University of Texas, Austin. Knowledge Based Systems (6/4/01 – 8/17/01)

Minh Binh Do, BS, 1998, Computer Science and Engineering, Arizona State University. Artificial intelligence with concentration on planning and scheduling. (6/11/01 – 9/28/01)

Alex David Groce, BS, 2001, Computer Science, Carnegie Mellon University, Model checking of Java programs (6/4/01 – 8/17/01)

Aaron Lee Gronstal, AS, 2001, Molecular Environmental Biology, UC Berkeley. Develop content for the Astrobiology Web Pages. (6/4/01 – 8/30/01)

Emmanuel Guere, MS, 1998, Artificial Intelligence, Paul Sabatier University, Task Planning is a dynamic world. (6/11/01 – 9/9/01)

Scott Johnson, BS, 1999, Computer Science, University of Wyoming. Automated formal methods. (6/11/01 – 8/17/01)

Charis Kaskiris, MS, 1996, International Trade Policy and Analysis, University of Michigan, Brahms modeling of a planetary astronaut/robot EVA. (5/28/01 – 12/31/01)

Solange Lemai, MS., 2000, Computer Engineering, IAAS-CNRS, France, Task planning and its integration into an autonomous agent architecture (6/11/01 – 8/19/01)

K. Flavio Lerda, MS, 2000 – Computer Engineering, Politecnico di Torino, Distributed and parallel model checking (7/27/00 – present)

Zara L. Mirmalek, BA, Public Administration, California State University, Hayward, Work Systems Design and Evaluation (06/12/00 – present)

Jonathan Moody, BS, Computer Science, University of Oklahoma, Program, Programming languages. (6/4/01 – 8/17/01)

Katherine Mullen, AA, 2000, Computer Science, Bard College, Bayesian Networks, Data Analysis Programs (6/4/01 – 8/17/01)

Brian Murphy, BS, Physics, Stanford University, Potential implementation methods and algorithms for quantum computing (06/26/00 – 06/15/01)

Romeo Sanchez Nigenda, MCS, 2000, Computer Science, Arizona State University, Artificial intelligence with concentration on Planning and Scheduling. (6/11/01 – 9/28/01)

Tae-young Oh, Device modeling and simulation, Stanford University. (1/1/98 – present)

Christoph Raith, BA, 1999, Physics, PH Ludwigsburg, Programming in C. Graphically slowing the memory usage for computers. (6/18/01 – 9/28/01)

Shyam Ramalingam, Chemical Engineering, University of Santa Barbara, Computer Modeling of deposition of Si Films using PECVD. (9/2/97 - present)

Maurice Ringer, MS, Signal and Information Processing, Adelaide University, Australia, High resolution 3D surface models from multiple images. (6/15/01 to 8/31/01)

Ivan Temesvari, B.S., Mathematics, Eastern Illinois University, Research of hemodynamics of t-cells with application to breast cancer (5/7/01 – present)

Satish Kumar Thittamaranahalli (T), BA, Computer Scientist, Stanford University, Diagnosis and tracking of hybrid models of physical systems (06/15/00 – 09/22/00) (6/18/01 – 9/22/01)

Kristin Brent Venable, MS, 2001, University of Padova, Italy, Computer Science and Mathematics, Soft temporal constraints (7/5/01 – 9/21/01)

Vandana Verma, MS, Robotics, Carnegie Mellon University, Probabilistic approach to fault diagnosis and detection (06/19/00 – 08/25/00) (6/1/01 – 8/30/01)

Michael Whalen, MS, Computer Science, University of Minnesota, Safety critical systems – languages and techniques for improving quality and reliability (6/4/01 – 8/24/01)

IV.F Science Council

Dr. Jeffrey M. Bradshaw, Chair, The Boeing Company

Dr. Nabil Adam, Rutgers University

Dr. David Bailey, Lawrence Berkeley Labs

Dr. Daniel G. Bobrow, Xerox Palo Alto Research Center

Dr. Burton I. Edelson, George Washington University

Dr. Ken Ford, University of West Florida

Dr. Abdollah Homaifar, North Carolina A&T State University

Dr. Mitchell P. Marcus, University of Pennsylvania

Dr. Alain Rappaport , Carnegie Mellon University